A PENTON PUBLICATION

THE HIGH SPEED ELECTRONICS GROUP

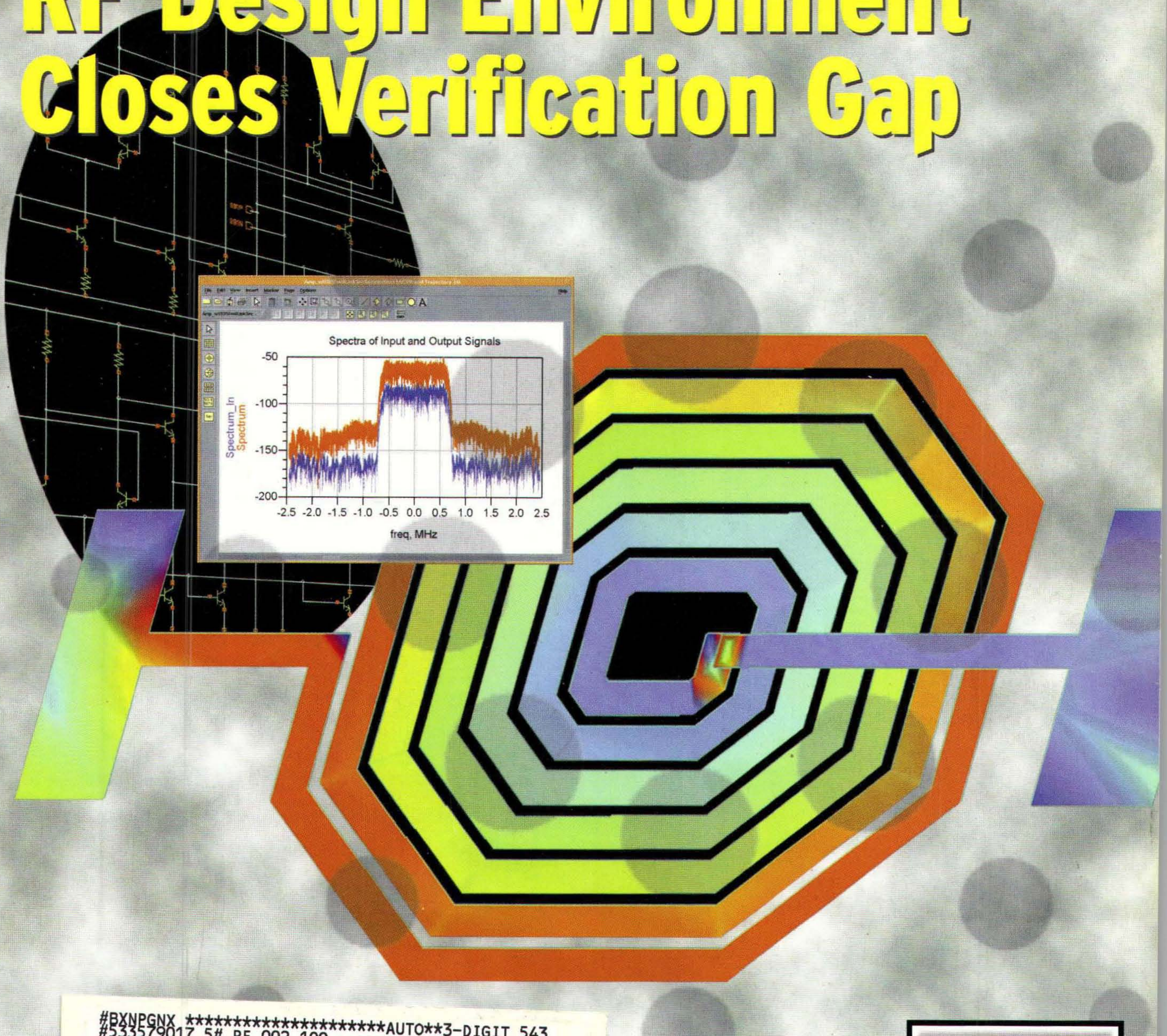
Microwaves & RF

News
Previewing device advances at the IEDM

Design Feature
Simple PBG structures serve microwave designs

Product Technology
Low-cost driver powers OC-192 optical modulators

RF Design Environment Closes Verification Gap



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JOE LORITZ, ENGINEER
GBPPR
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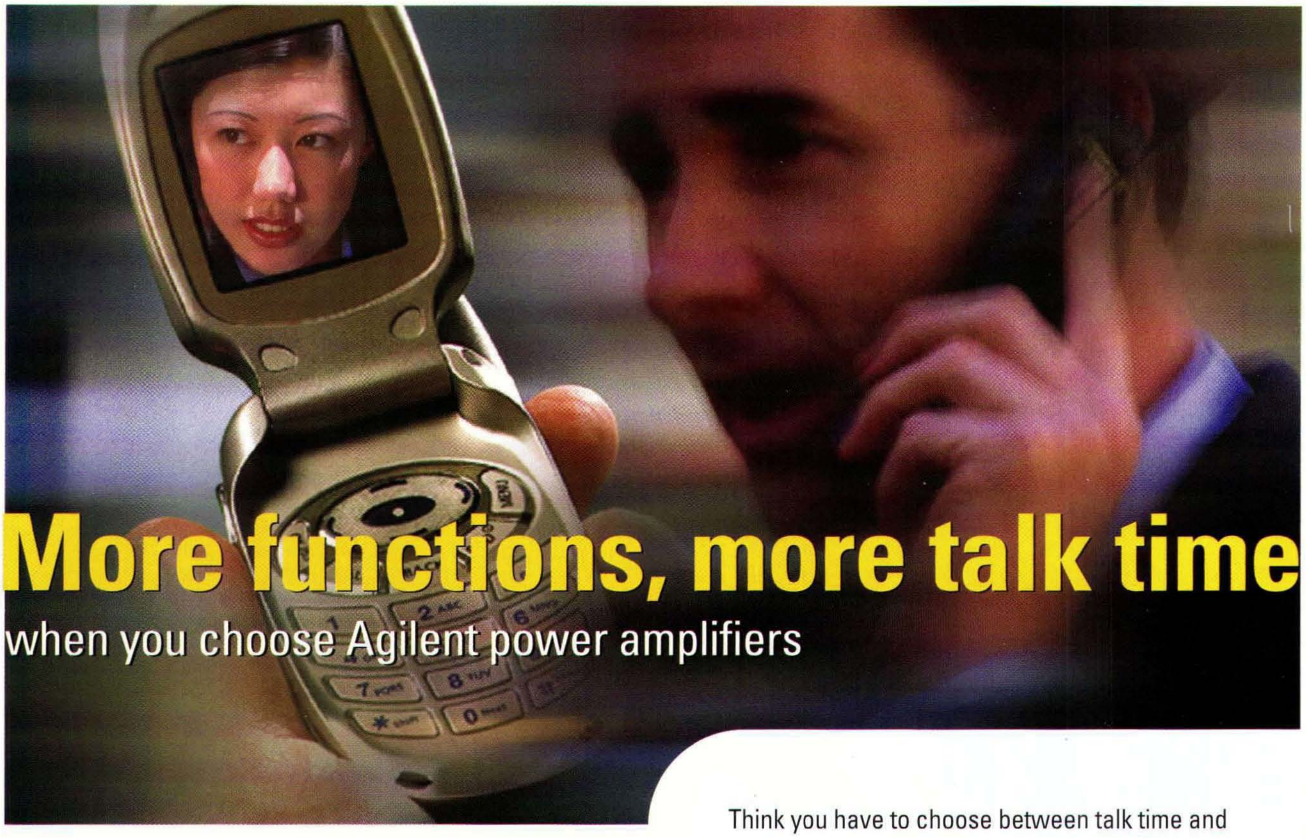
Microwaves & Optics Issue



Think you have to choose between talk time and new features? Think again! Agilent's new E-pHEMT power amplifiers deliver the industry's best power-added efficiency, so now you can have both.

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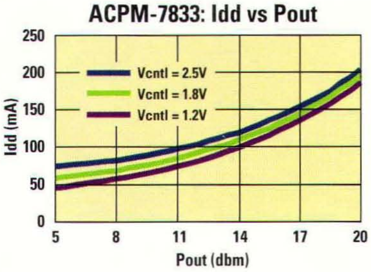
How does Agilent's E-pHEMT stack-up against HBT solutions? For the answer, visit us at **www.agilent.com/view/ephemt**

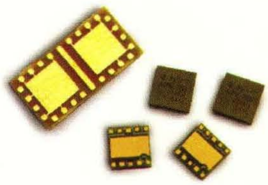
CDMA PAs: Efficiency at Low Vdd

	PAE (%)			
Vdd1 & Vdd2 (V)	3.4	2.0	1.0	Freq (MHz)
ACPM-7833	6.2	10.2	18.2	1880
ACPM-7813	6.1	10.1	18.6	836

Test conditions: Pout = 14dBm Vbias = 3.4V

ACPM-7833: Idd vs Pout





www.agilent.com/view/ephemt

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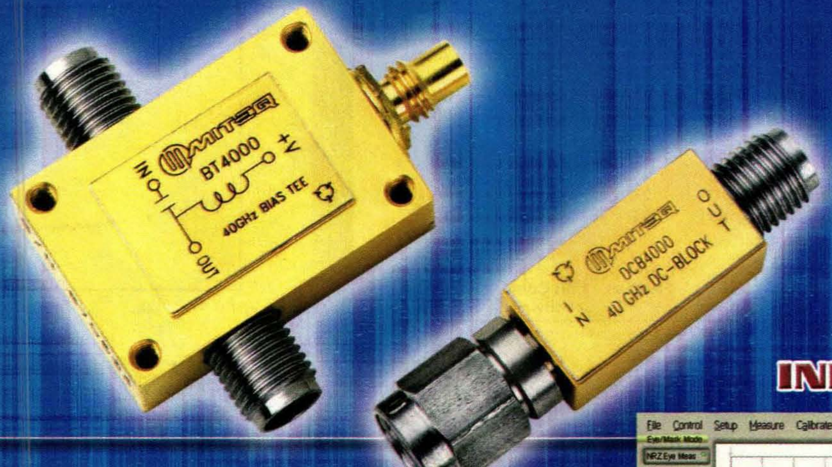
BIAS TEE & DC BLOCK

SPECIFICATIONS:

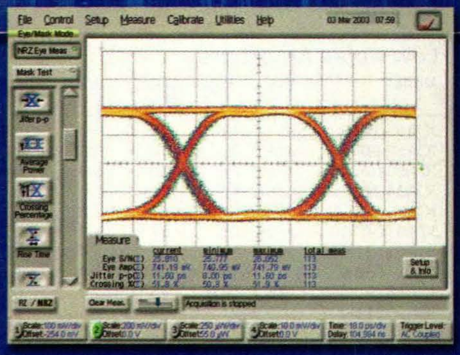
- 30 kHz To 40 GHz
- < 1.5 dB Insertion Loss
- < 2:1 VSWR (In/Out)
- < +25V Maximum Voltage
- < 150 mA Maximum Current

SPECIFICATIONS:

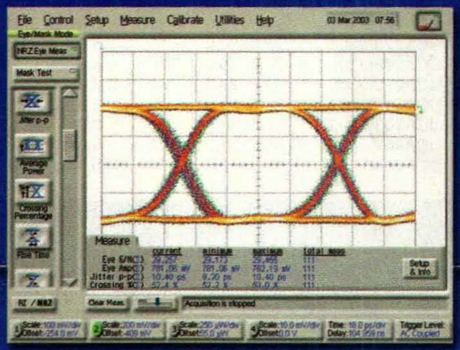
- 30 kHz To 40 GHz
- < 1.3 dB Insertion Loss
- < 2:1 VSWR (In/Out)



INPUT



OUTPUT



APPLICATIONS:

- Optical communication systems where broad bandwidth is needed

FEATURES:

- Connectorized or true surface mount for lower frequency (30 kHz - 20 GHz) models
- Low insertion loss
- Compact designs

OPTIONS:

- Available with various bandwidths
- Custom designs
- Military screening

ISO 9001:2000 Certified

For additional information, contact Naseer Shaikh at (631) 439-9296 or nshaikh@miteq.com

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Broadband Power Amplifiers NEW

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ
JCA018-3000	2.0–18.0	25	6.0	2.0	23	28
JCA218-3001	2.0–18.0	25	6.0	2.0	25	30
JCA218-3002	2.0–18.0	25	6.0	2.0	27	32
JCA218-4000	2.0–18.0	30	6.0	2.0	23	28
JCA218-4001	2.0–18.0	30	6.0	2.0	25	30
JCA218-4002	2.0–18.0	30	6.0	2.0	27	32
JCA218-5000	2.0–18.0	35	6.0	2.0	23	28
JCA218-5001	2.0–18.0	35	6.0	2.0	25	30
JCA218-5002	2.0–18.0	35	6.0	2.0	27	32

Power Amplifiers

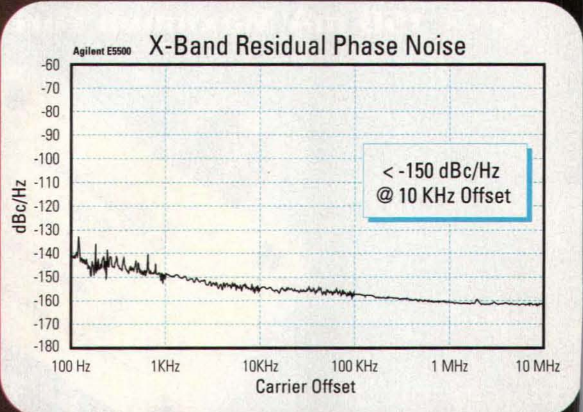
Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ
JCA12-P01	1.35–1.85	35	4.0	1.0	33	41
JCA34-P02	3.1–3.5	40	4.5	1.0	37	45
JCA56-P01	5.9–6.4	30	5.0	1.0	34	42
JCA812-P03	8.0–12.0	40	5.0	1.5	33	40
JCA1218-P02	12.0–18.0	22	4.0	2.0	25	35

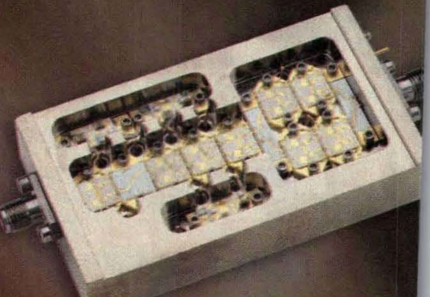
Low Noise Amplifiers

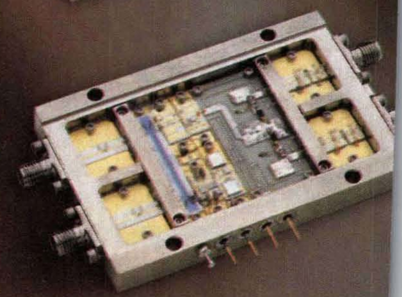
Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ
JCA12-1000	1.2–1.6	25	0.8	0.5	10	20
JCA12-3001	1.0–2.0	40	0.8	1.0	10	20
JCA23-302	2.2–2.3	30	0.8	0.5	10	20
JCA34-301	3.7–4.2	30	1.0	0.5	10	20
JCA78-300	7.25–7.75	27	1.2	0.5	13	23
JCA910-3000	9.0–9.5	25	1.3	0.5	13	23
JCA1112-3000	11.7–12.2	27	1.4	0.5	13	23
JCA1415-3001	14.4–15.4	35	1.6	1.0	14	24
JCA1819-3001	18.1–18.6	25	2.0	0.5	10	20
JCA2021-3001	20.2–21.2	25	2.5	0.5	10	20

Millimeter Wave Amplifiers

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ
JCA2629-201	26.0–29.0	19	5.0	1.5	5	15
JCA2629-401	26.0–29.0	35	5.0	1.5	5	15
JCA2730-205	27.5–30.0	15	5.0	1.0	15	25
JCA2730-302	27.5–30.0	26	5.0	1.0	8	18
JCA2730-502	27.5–30.0	43	5.0	1.0	8	18
JCA3031-102	30.0–31.0	18	5.0	1.5	8	18
JCA3031-302	30.0–31.0	34	5.0	1.5	8	18
JCA3031-405	30.0–31.0	40	5.0	1.5	15	25
JCA2640-301	26.5–40.0	30	5.0	2.5	0	10







Integrated Functions/Options

- Variable Gain Control
- TTL Switching
- Temperature Compensation
- Input/Output Isolators
- Waveguide Interface
- Detector Output
- Input Limiters
- Phase Matching
- Gain Matching
- Limiting Amplifiers
- Hermetic Packages
- Bias-T Output

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10G

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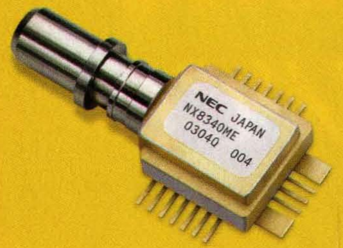


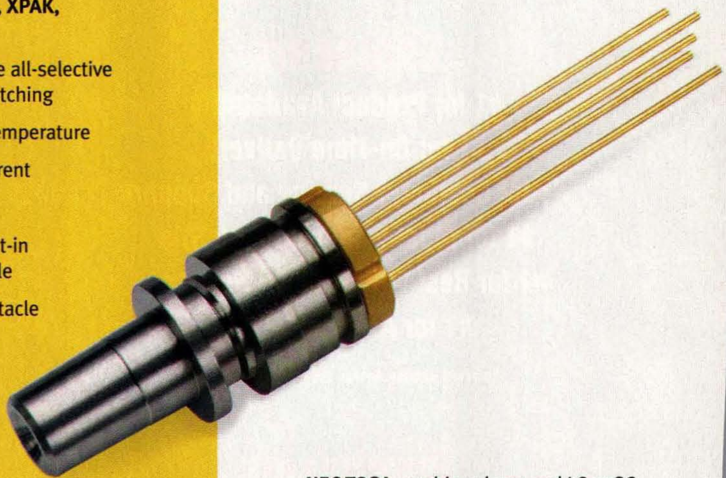
10G Uncooled 1310nm DFB DMLs

For 300 Pin Transponders, XENPAK, XPAK, X2, and XFP Transceivers

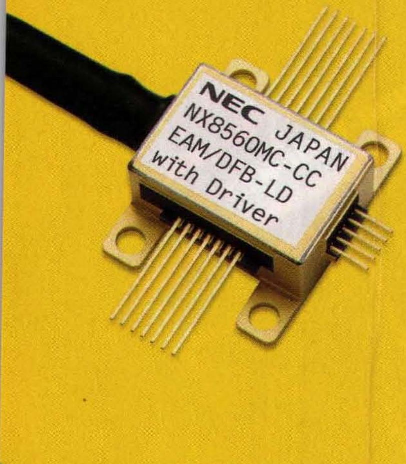
- Fabricated using Al oxidation-free all-selective MOVPE without semiconductor etching
- Outstanding performance over temperature
- Low threshold and operation current

Several versions available:

- Surface mount package with built-in Driver IC — pigtail or SC receptacle
- 5.6mm TOSA with LC or SC receptacle (without Driver IC)



NEC TOSA *combines laser and LC or SC receptacle in a single miniature module. The pluggable fiber-to-laser design eliminates optical alignment problems and guarantees a fixed optical coupling.*

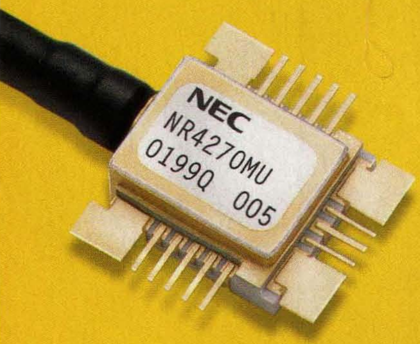


10G EML Modules

For Long Haul and 10G Transponders

Several versions available:

- With integrated Driver IC in MSA package
- With integrated Wavelength Monitor in butterfly package with GPO™ connector
- In butterfly package with GPO™ connector



Surface mount package coming soon

10G PIN+TIA & APD+TIA Detectors

For Ultra Long Haul, Long Haul, Metro and 10G Transponder/Transceiver applications

- High Sensitivity PIN and Superlattice APD versions, with integrated low noise GaAs transimpedance amplifier
- AC coupled diferential output
- ROSA package with LC or SC receptacle also available

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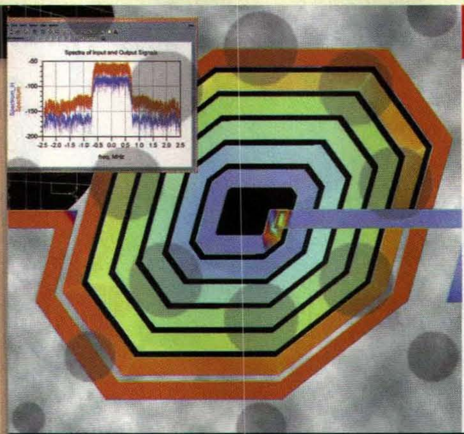

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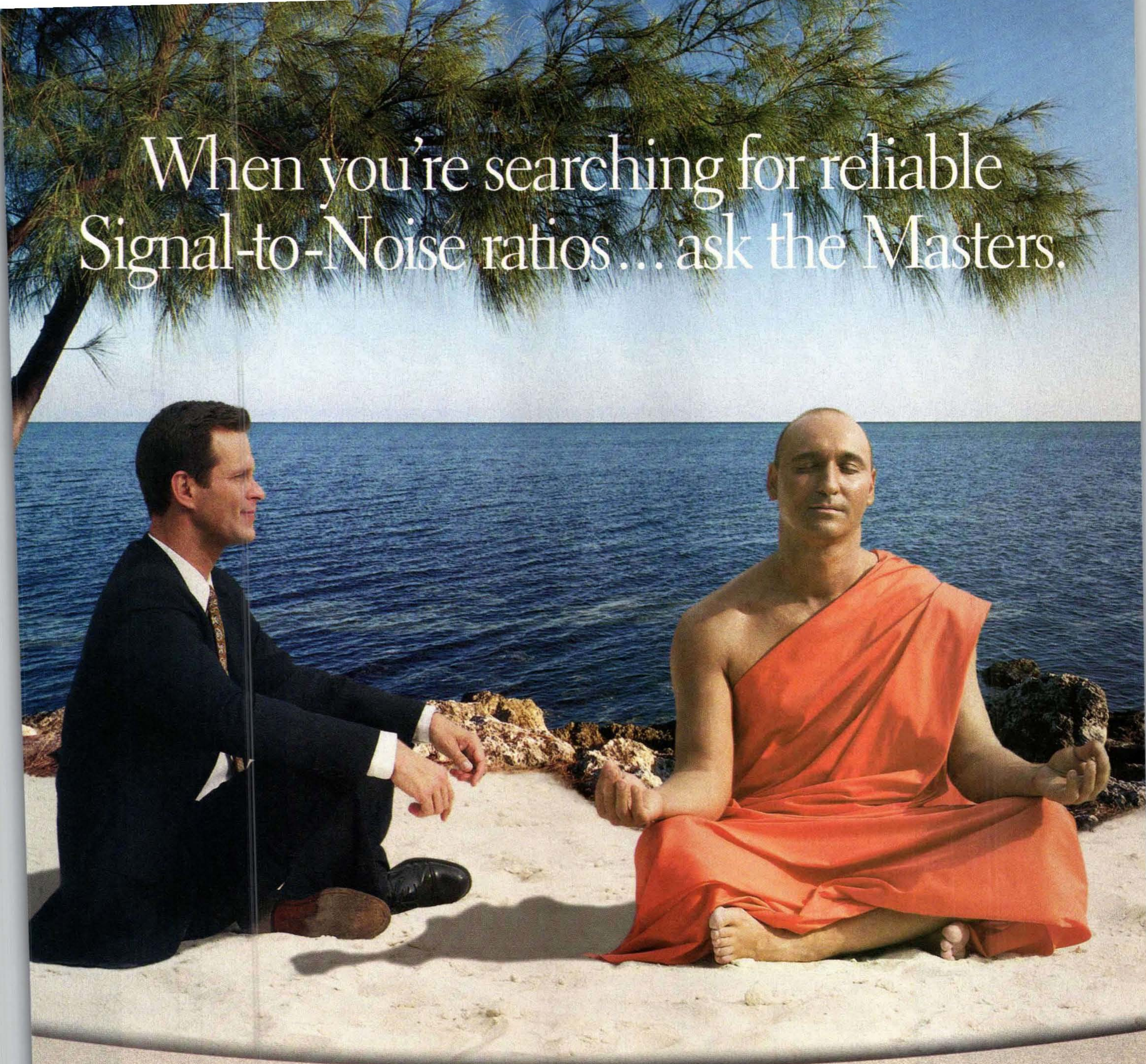

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Ultra-Low Noise AMPLIFIERS VHF To V-BAND

MODEL NUMBER	FREQUENCY RANGE (GHz)	GAIN (dB, Min.)	GAIN VARIATION (±dB, Max.)	NOISE FIGURE (dB, Max.)	VSWR IN	VSWR OUT	POWER OUT @ 1 dB COMP. (dBm, Min.)	DC POWER @ +15 V (mA, Nom.)
OCTAVE BAND AMPLIFIERS								
JS2-00500100-045-5A	0.5 – 1	35	1	0.45	2:1	2:1	5	250
JS2-00500100-12-5A	0.5 – 1	35	1.2	1	2:1	2:1	5	250
JS2-01000200-045-5A	1 – 2	33	1	0.45	2:1	2:1	5	250
JS2-02000400-045-5A	2 – 4	28	1.2	0.45	2:1	2:1	5	175
JS2-04000800-08-0A	4 – 8	22	1.2	0.8	2:1	2:1	0	150
JS3-04000800-08-5A	4 – 8	30	1	0.8	2:1	2:1	5	175
JS3-04000800-15-5A	4 – 8	30	1	1.5	2:1	2:1	5	175
JS2-08001200-11-5A	8 – 12	15	1	1.1	2:1	2:1	5	150
JS3-08001200-11-5A	8 – 12	25	1	1.1	2:1	2:1	5	175
JS3-08001200-15-5A	8 – 12	25	1	1.5	2:1	2:1	5	175
JS3-12001800-16-5A	12 – 18	23	1	1.6	2:1	2:1	5	175
JS4-12001800-145-5A	12 – 18	30	1	1.45	2:1	2:1	5	200
JS4-12001800-30-5A	12 – 18	30	1	3	2:1	2:1	5	200
JS2-18002600-20-5A	18 – 26	14	2	2	2.5:1	2.5:1	5	100
JS2-18002600-30-5A	18 – 26	14	2	3	2.5:1	2.5:1	5	100
JS3-18002600-20-5A	18 – 26	22	1.8	2	2.5:1	2.5:1	5	175
JS3-18002600-30-5A	18 – 26	22	1.8	3	2.5:1	2.5:1	5	175
JS4-18002600-19-5A	18 – 26	33	1.5	1.9	2:1	2:1	5	200
JS4-18002600-26-5A	18 – 26	33	1.5	2.6	2:1	2:1	5	200
JS2-26004000-35-5A	26 – 40	10	2	3.5	2.5:1	2.5:1	5	100
JS2-26004000-45-5A	26 – 40	10	2	4.5	2.5:1	2.5:1	5	100
JS3-26004000-35-5A	26 – 40	18	2.5	3.5	2.5:1	2.5:1	5	175
JS3-26004000-45-5A	26 – 40	18	2.5	4.5	2.5:1	2.5:1	5	175
JS4-26004000-40-5A	26 – 40	23	2.5	4	2:1	2:1	5	200
JS4-40006000-65-0A	40 – 60	15	3	6.5	2.75:1	2.75:1	0	175
MULTIOCTAVE BAND AMPLIFIERS								
JS2-00500200-07-5A	0.5 – 2	32	1	0.7	2:1	2:1	5	295
JS2-00500200-15-5A	0.5 – 2	32	1	1.5	2:1	2:1	5	295
JS2-01000400-08-5A	1 – 4	27	1	0.8	2:1	2:1	5	200
JS2-01000400-20-5A	1 – 4	27	1	2	2:1	2:1	5	200
JS2-02000600-08-5A	2 – 6	22	1	0.8	2:1	2:1	5	125
JS2-02000600-20-5A	2 – 6	22	1	2	2:1	2:1	5	125
JS2-02000800-08-0A	2 – 8	22	1.25	0.8	2:1	2:1	0	125
JS2-02000800-20-0A	2 – 8	18	1.25	2	2:1	2:1	0	125
JS3-02001800-25-5A	2 – 18	23	1.8	2.5	2.5:1	2.5:1	5	150
JS3-02001800-50-5A	2 – 18	23	1.8	5	2.5:1	2.5:1	5	150
JS4-02001800-22-5A	2 – 18	30	2	2.2	2.5:1	2.5:1	5	200
JS4-02001800-50-5A	2 – 18	30	2	5	2.5:1	2.5:1	5	200
JS3-02002600-33-5A	2 – 26	21	2.5	3.3	2.5:1	2.5:1	5	150
JS3-02002600-40-5A	2 – 26	21	2.5	4	2.5:1	2.5:1	5	150
JS3-06001800-16-5A	6 – 18	23	1.8	1.6	2:1	2:1	5	125
JS3-06001800-30-5A	6 – 18	23	1.8	3	2:1	2:1	5	125
JS4-06001800-145-5A	6 – 18	31	2	1.45	2:1	2:1	5	200
JS4-06001800-30-5A	6 – 18	31	2	3	2:1	2:1	5	200

MITEQ's JS SERIES AMPLIFIERS

- High Performance/Price Ratio
- Superior, Rugged Technology
- Low Phase Distortion Design

Actual
18 to 40 GHz Design

MODEL NUMBER	FREQUENCY RANGE (GHz)	GAIN (dB, Min.)	GAIN VARIATION (±dB, Max.)	NOISE FIGURE (dB, Max.)	VSWR IN	VSWR OUT	POWER OUT @ 1 dB COMP. (dBm, Min.)	DC POWER @ +15 V (mA, Nom.)
MULTIOCTAVE BAND AMPLIFIERS (continued)								
JS3-08001800-16-5A	8 – 18	24	1.5	1.6	2:1	2:1	5	150
JS3-08001800-30-5A	8 – 18	24	1.5	3	2:1	2:1	5	150
JS4-08001800-145-5A	8 – 18	32	2	1.45	2:1	2:1	5	200
JS4-08001800-30-5A	8 – 18	32	2	3	2:1	2:1	5	200
JS3-12002600-25-5A	12 – 26	22	2.5	2.5	2.2:1	2.2:1	5	150
JS3-12002600-35-5A	12 – 26	22	2.5	3.5	2.2:1	2.2:1	5	150
JS4-12002600-22-5A	12 – 26	32	2.2	2.2	2:1	2:1	5	200
JS4-12002600-35-5A	12 – 26	32	2.2	3.5	2:1	2:1	5	200
JS3-18004000-38-5A	18 – 40	16	2.5	3.8	2.5:1	2.5:1	5	150
JS3-18004000-50-5A	18 – 40	16	2.5	5	2.5:1	2.5:1	5	150
JS4-18004000-30-5A	18 – 40	23	2.5	3	2.5:1	2.5:1	5	200
JS4-18004000-50-5A	18 – 40	23	2.5	5	2.5:1	2.5:1	5	200
ULTRAWIDE BAND AMPLIFIERS								
JS2-00100200-07-5A	0.1 – 2	32	1	0.7	2:1	2:1	5	295
JS2-00100200-15-5A	0.1 – 2	32	1	1.5	2:1	2:1	5	295
JS2-00100400-08-5A	0.1 – 4	27	1	0.8	2:1	2:1	5	200
JS2-00100400-12-5A	0.1 – 4	27	1	1.2	2:1	2:1	5	200
JS2-00100600-10-3A	0.1 – 6	23	1.5	1	2:1	2:1	3	175
JS2-00100600-20-3A	0.1 – 6	23	1.5	2	2:1	2:1	3	175
JS2-00100800-13-0A	0.1 – 8	20	1.5	1.3	2:1	2:1	0	175
JS2-00100800-25-0A	0.1 – 8	20	1.5	2.5	2:1	2:1	0	175
JS3-00101000-20-5A	0.1 – 10	23	1.5	2.0	2.5:1	2:1	5	150
JS3-00101000-35-5A	0.1 – 10	23	1.5	3.5	2.5:1	2:1	5	150
JS3-00101200-21-5A	0.1 – 12	23	1.5	2.1	2.5:1	2:1	5	150
JS3-00101200-35-5A	0.1 – 12	23	1.5	3.5	2.5:1	2:1	5	150
JS3-00101800-24-5A	0.1 – 18	23	1.8	2.4	2.5:1	2.2:1	5	150
JS3-00101800-40-5A	0.1 – 18	23	1.8	4	2.5:1	2.2:1	5	150
JS4-00101800-23-5A	0.1 – 18	29	1.8	2.3	2.5:1	2.2:1	5	200
JS4-00101800-40-5A	0.1 – 18	29	1.8	4	2.5:1	2.2:1	5	200
JS4-00102000-25-5A	0.1 – 20	28	1.8	2.5	2.5:1	2.5:1	5	200
JS4-00102000-35-5A	0.1 – 20	28	1.8	3.5	2.5:1	2.5:1	5	200
JS3-00102600-33-5A	0.1 – 26	20	2.5	3.3	2.5:1	2.5:1	5	150
JS3-00102600-42-5A	0.1 – 26	20	2.5	4.2	2.5:1	2.5:1	5	150
JS4-00102600-28-5A	0.1 – 26	27	2.5	2.8	2.5:1	2.5:1	5	200
JS4-00102600-50-5A	0.1 – 26	27	2.5	5	2.5:1	2.5:1	5	200
JS4-00104000-65-5A	0.1 – 40	14	4.5	6.5	2.75:1	2.75:1	5	200
JS4-00104000-85-5A	0.1 – 40	14	4.5	8.5	2.75:1	2.75:1	5	200

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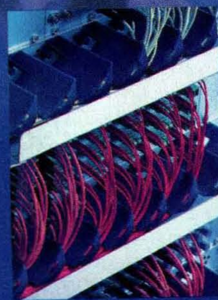

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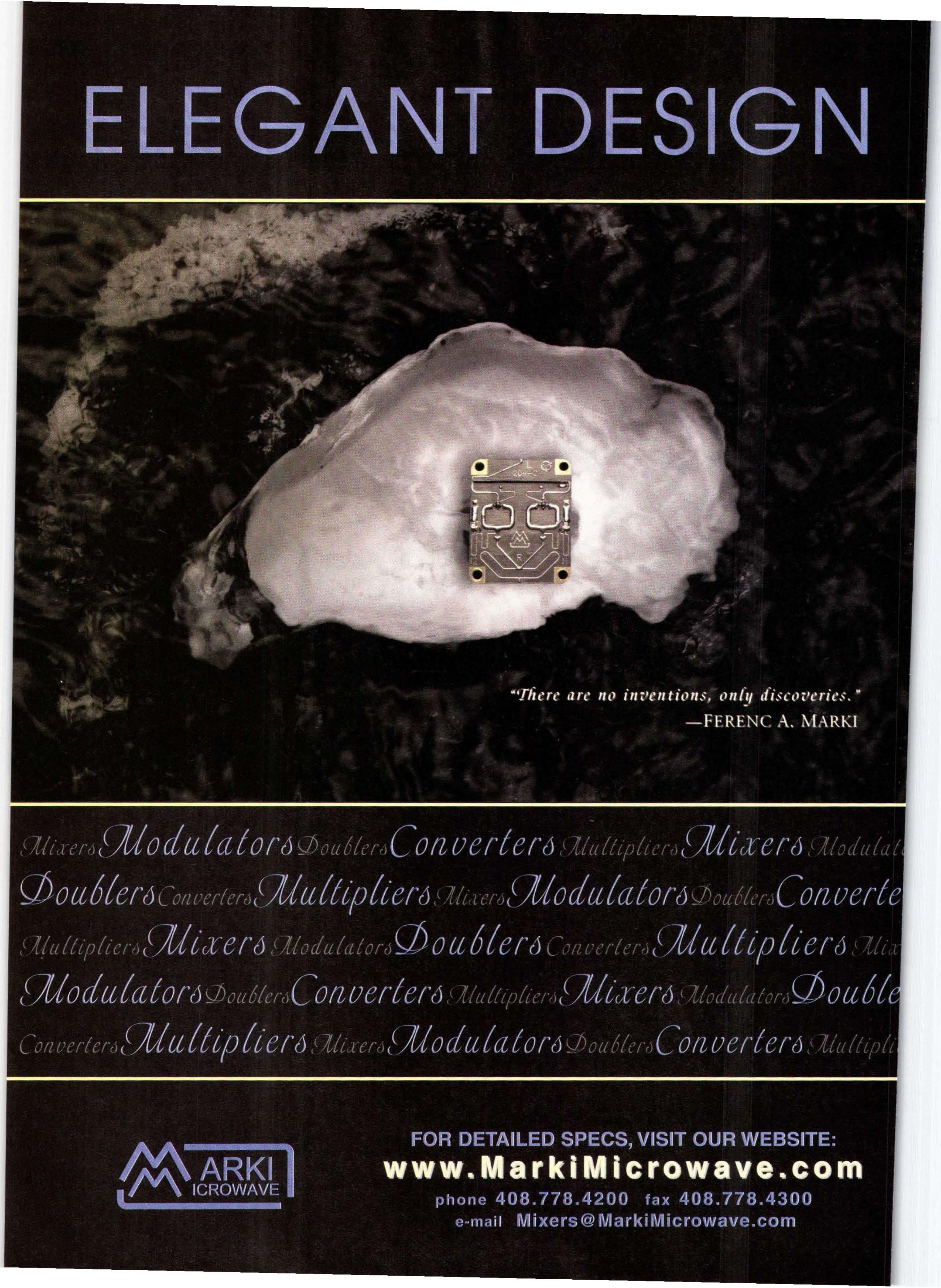
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Contents Correction

▸▸THE TABLE OF CONTENTS in the October 2003 issue (p. 5) listed the Cover Story, "SiGe Modulators Ease Upconverter Design," as beginning on p. 100. The article actually begins on p. 78. The incorrect page number was published due to an editorial error. We apologize to the readers for any confusion that this error may have caused.

The Editors of Microwaves & RF

R&D Roundup Error

▸▸THERE IS A small error in the R&D Roundup section in the September 2003 issue (p. 48). The heading for section three reads, "Measure ADC Noise By Cross Correlation," but the text indicates an article on LTCC/Bandpass filter.

Minh Nguyen
Philips Semiconductors—Sophia

Editor's Note: Thanks for pointing out the error. The head that appeared, "Measure ADC Noise By Cross Correlation," is a head from the template page. It should have been replaced by the correct head, which was, "Deep Embedded Interconnects Support Thick LTCC Circuits." Microwaves & RF *regrets the error, and we apologize for any confusion over the error.*

PLEASE COMMENT

Microwaves & RF welcomes mail from its readers. Letters must include the writer's name and address. The magazine reserves the right to edit letters appearing in "Feedback." Address letters to:

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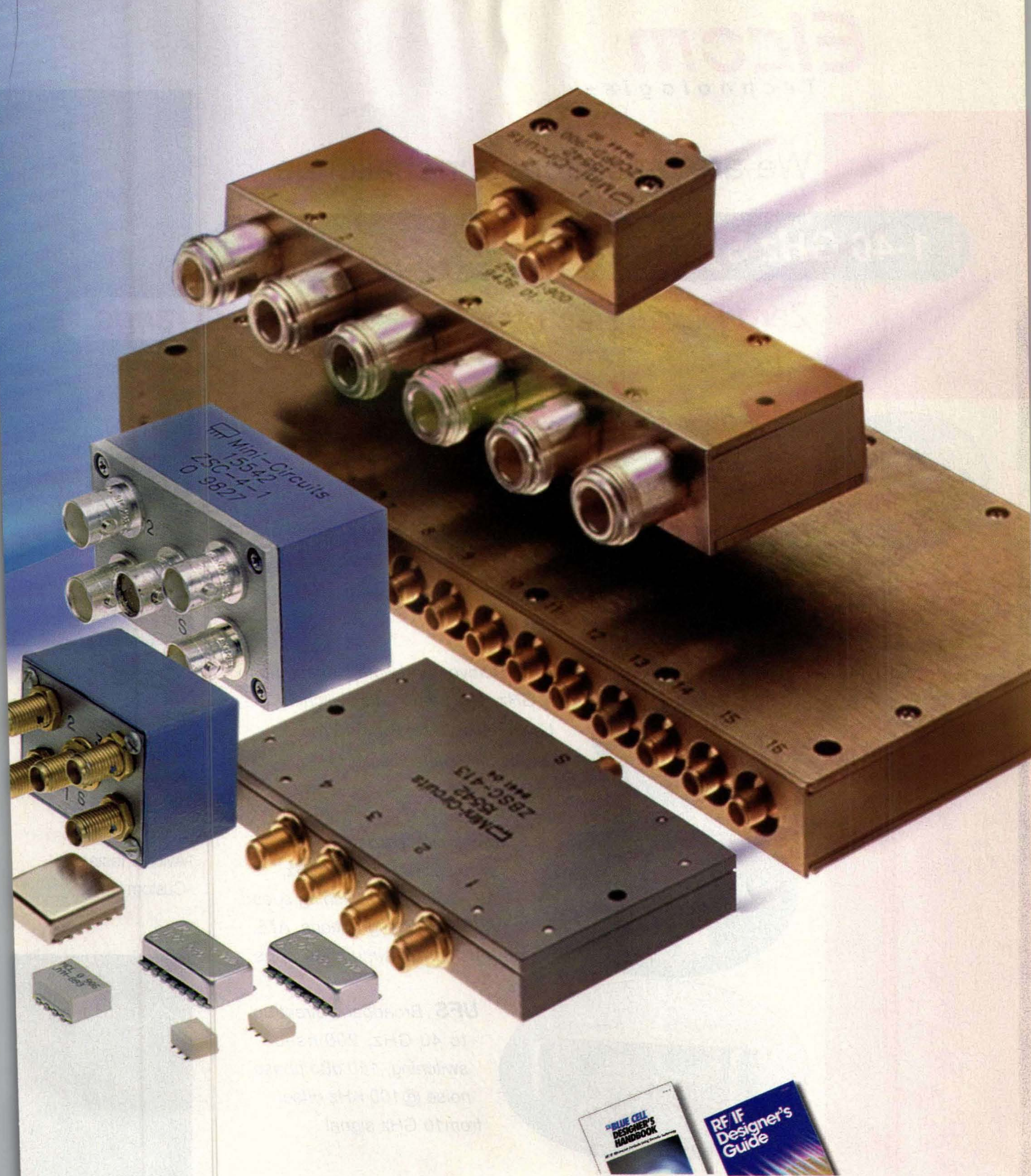

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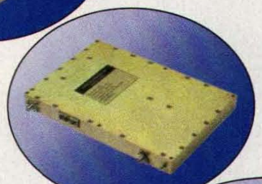

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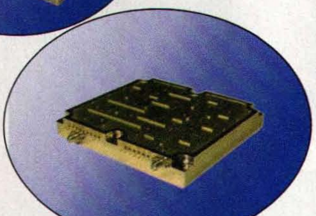

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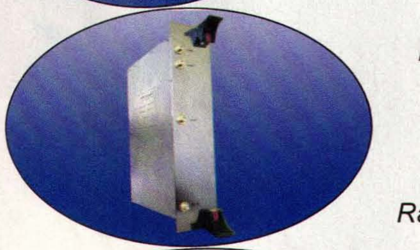

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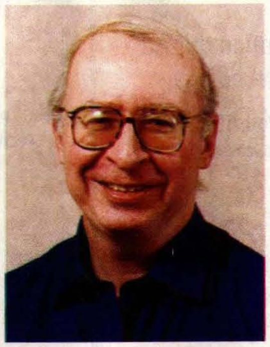
The Propagation Of RF Technology



ONCE UPON A TIME, researchers discovered that radio waves could be used for more than just radios. As radar technology blossomed during World War II, an industry took root, growing steadily on a diet of largely military applications, such as electronic warfare (EW), signal intelligence (SIGINT), and electronic countermeasures (ECM). Some 50 years later, the industry finally found itself with real commercial business as wireless markets crystallized in the late 1980s.

The more that RF propagates, the healthier this industry will become.

That was then, and this is now. The cellular "sleigh ride" that the industry enjoyed for the past decade has braked to an abrupt halt for many, although military business again looks appealing. But aren't there more uses for RF technology than cellular communications and military systems?

In fact, RF/wireless technologies have been in use for many years in industrial and medical environments, and will play increasingly important roles in automotive engineering. In industrial applications, low-power, low-data-rate transmitters and receivers have supported sensors in process-control and inventory applications for decades. In medical environments, magnetic resonance imaging (MRI) may be the most noteworthy RF application, but such uses as wireless hospitals, telemetry, and implantable monitors are quickly gaining ground.

In recognizing the long-term need for this industry to rely more on just commercial and military avenues, next year *Microwaves & RF* will expand its coverage into areas that may be nontraditional, but represent opportunities for RF/microwave technology (see Editorial Calendar).

ISSUE	THEME
January	Test & Measurement
February	Semiconductors
March	Communications
April	Wireless Technology
May	MTT-S Preview/Radar & Antennas
June	Defense Electronics
July	Amplifiers & Oscillators
August	Wireless Applications
September	Military Electronics
October	Emerging Technologies
November	Computer-Aided Engineering
December	Communications

Certainly, if you are working in some of these growing application areas, such as automotive (telematics), industrial, or medical designs, we'd like to hear how we could help you with your design problems. In more ways than one, the more that RF propagates, the healthier this industry will become.

Jack Browne

Publisher/Editor

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CWC501-XXX*	50:1	1.4:1	0.60	0.40	0.95	4.0	5
CWC641-XXX*	64:1	1.4:1	0.60	0.50	1.20	5.0	8
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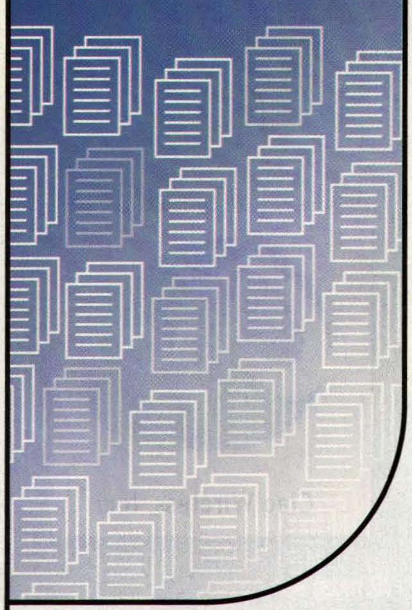

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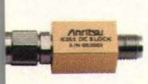

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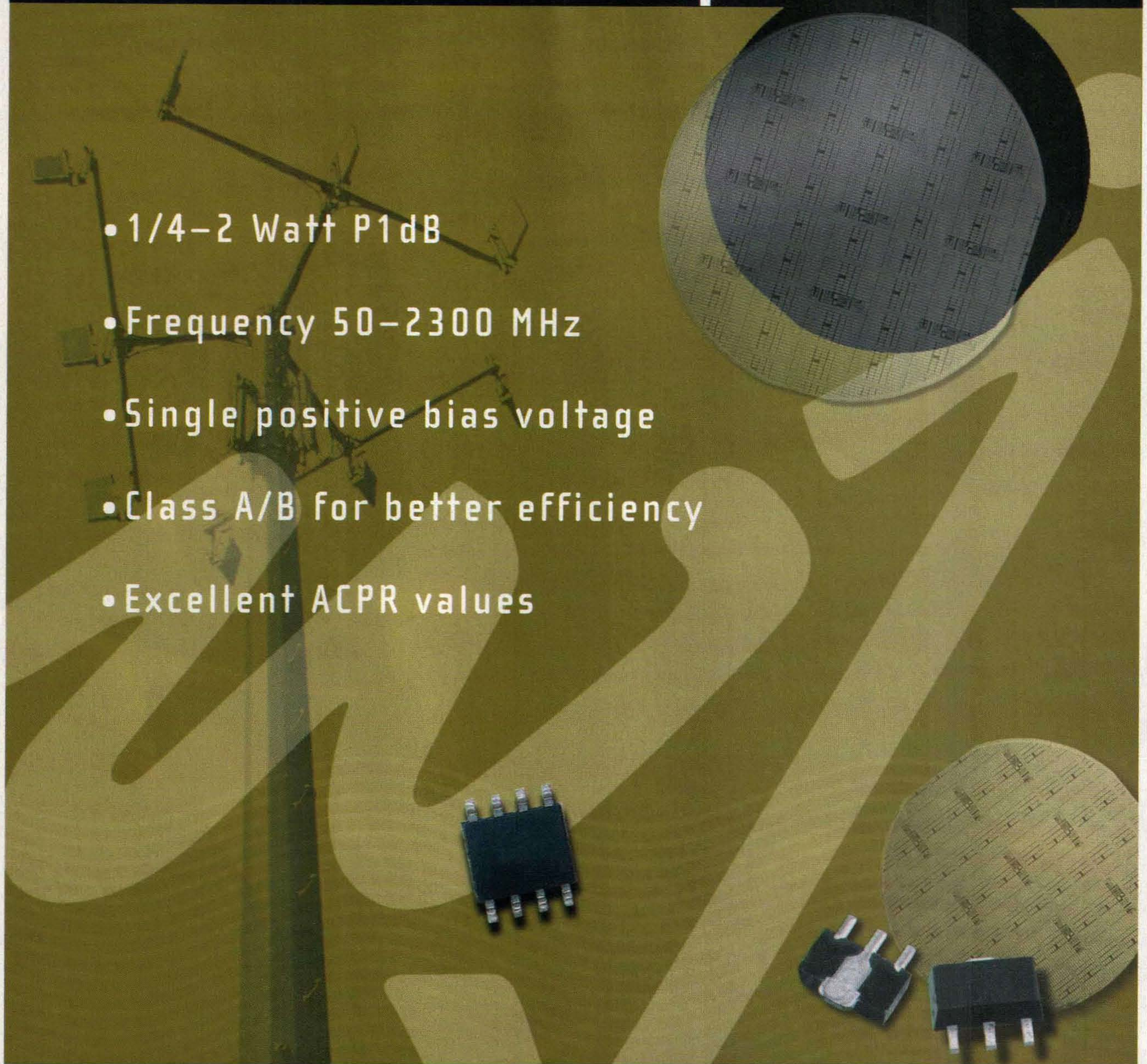

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AH116	800-1000	+28	+42	18.0	6.0	+16 (-65 dBc)	+5/250	SOIC-8
AH215	400-2300	+31	+47	17.0	6.5	+21 (-60 dBc)	+5/450	SOIC-8
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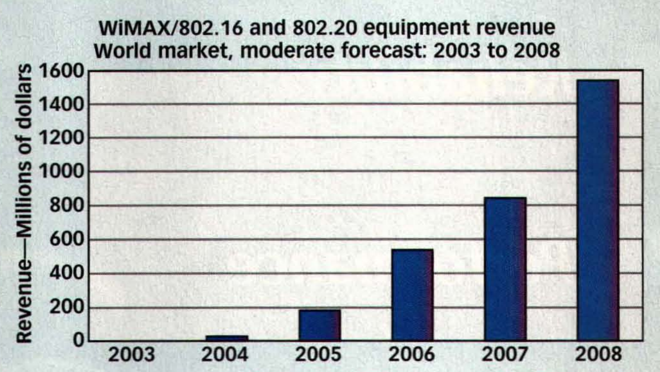
the front end

News items from the communications arena.

The Future Of WiMAX Is In The Hands Of The Carriers

OYSTER BAY, NY—Traditional wire-line carriers and wireless operators are trying to determine how—if at all—to embrace WiMAX technology. Technology market-research firm Allied Business Intelligence, Inc. (ABI), in a report entitled, "WiMAX / 802.16 and 802.20: New Standards Revitalizing Broadband Wireless Access," estimates that combined revenues of equipment for WiMAX and IEEE 802.20, another standard currently in development, will exceed $1.5 billion in 2008 **(see figure)**.



(Source: Allied Business Intelligence, Inc.)

The majority of this will be WiMAX equipment, an 802.20-compliant gear will not likely reach the market until 2006. Companies developing compliant equipment include Alvarion, Aperto, and Flarion, among others.

"Growth in equipment spending will be very strong, though much smaller in absolute terms compared to that of cellular networks," states ABI's director of research, Edward Rerisi. "But if this technology begins to gain traction, network effects may accelerate adoption and drive revenues even higher."

Specifically, recent research from ABI reveals that support from at least one major carrier will push this market into a wide-scale opportunity, beyond a niche opportunity for regional service providers. However, key to this development will be careful planning by the incumbents to determine how to best utilize this emerging wireless technology—just as they begin to digest their moves with Wi-Fi, another disruptive technology.

US Air Force Taps Raytheon To Design Anti-Jam GPS Navigator

EL SEGUNDO, CA—Raytheon Co. was recently selected by the US Air Force Research Laboratory (AFRL) to develop a miniaturized Global Positioning System (GPS) navigator with an adaptive anti-jam capability for the Miniature Navigator Demonstration (MIND) program.

Under the $6.9 million program research-and-development (R&D) contract, Raytheon Space and Airborne Systems will design and demonstrate a smaller, lighter, and more cost-effective weapon navigator system that is capable of operating in a dynamic, high-speed flight environment against various GPS jammer threats.

It will combine an integrated 24-channel GPS receiver, a state-of-the-art inertial measurement unit, adaptive processing algorithms, and A/J front-end hardware that will be compatible with the future GPS M-code satellite signals. This development will build on Raytheon's proven success on AFRL's current Advanced GPS Inertial Navigation Technology (AGINT) program.

"Raytheon's AGINT technology has already been transitioned into our Digital Anti-jam Receiver product, which is suitable for aircraft and cruise-missile applications," comments David Lewis, GPS technologies manager for Raytheon Precision Guidance Systems. "Under the MIND program, Raytheon is developing a highly innovative miniaturized digital adaptive A/J design for inclusion in smaller munitions and weapons systems."

Precision Guidance Systems designs and develops integrated navigation systems for weapons, avionics, and handheld applications.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Lucent Teams With AT&T Wireless To Trial 3G WCDMA

MURRAY HILL, NJ—Lucent Technologies announced that it is working with AT&T Wireless to deploy a third-generation (3G) WCDMA trial network in the greater Miami, FL area to evaluate mobile voice and high-speed data services.

Lucent is supplying AT&T Wireless with an end-to-end mobile network based on 3G WCDMA technology, also known as Universal Mobile Telecommunications System (UMTS). The network will incorporate Lucent's Flexent® OneBTS® base stations and core packet networking solution—which includes the Lucent Softswitch and data-networking platforms from Cisco Systems, Inc., including the Cisco Gateway GPRS Support Node (GGSN) and MGX 8000 Series Media Gateways.

Lucent is also supplying AT&T Wireless with WCDMA wireless PC modem cards, which support high-speed data connections on laptops, PDAs, and other mobile devices.

"Lucent's solution offers us a great opportunity to explore and evaluate the range of services that 3G WCDMA will enable us to make available to our customers," says Eric Updyke, vice president for 3G program management at AT&T Wireless.

"3G WCDMA will enable businesses to provide their employees with high-speed mobile access to their corporate networks."

Third-generation WCDMA will enable people to download video clips of films, sporting, and entertainment events; send and receive e-mail on the go; and locate nearby services, such as ATMs, restaurants, or theaters. This advanced mobile-communications technology also will enable businesses to provide their employees, such as field-service personnel, with high-speed mobile access to their corporate networks and business applications they normally use in the office.

"AT&T Wireless is a leader in the introduction of cutting-edge wireless services in North America," states Roger Derrien, vice president for UMTS product management with Lucent's Mobility Solutions Group. "We're pleased to be working with them on this trial deployment of 3G high-speed data and multimedia services."

The WCDMA network will operate in AT&T Wireless' 1900-MHz spectrum, and will be based on an Internet Protocol (IP) architecture that can offer substantial increases in network efficiency, and support a wide variety of multimedia services.

While this is the first trial in North America, Lucent has additional 3G WCDMA/UMTS pilot network deployments underway in Europe. Lucent has deployed more than 80,000 spread-spectrum base stations for mobile operators worldwide. Spread-spectrum technology is the basis for 3G WCDMA (UMTS) and CDMA2000 networks.

Anritsu Announces Partnership With TestMart

RICHARDSON, TX—Anritsu Co., a test and measurement solutions firm, has announced a partnership with TestMart, a marketplace operator and service provider for the test and measurement industry, whereby TestMart will provide a set of government marketplace services to Anritsu Co.

The agreement authorizes TestMart to offer a catalog of Anritsu products that will be made available for sale specifically in the government and military channel. TestMart will offer this catalog under a set of General Services Administration (GSA) Multiple Award Schedules and will provide to Anritsu content, transaction, marketing, and reporting services to help support the sale of the products in the catalog. TestMart will provide the presentation and ordering processing of these products through the GSA's e-commerce website, GSA Advantage!, and through TestMart's NAVICPmart service, a test equipment e-commerce marketplace operated under contract from the federal government specifically for the use of the US military, federal agencies, and their contractors.

Under terms of the partnership, Anritsu's test solutions that are applicable for military and government applications will be available. These test solutions include OTDRs, signal generators, Site Master handheld cable and antenna analyzers, vector network analyzers, and tunable laser sources, as well as high-speed devices.

The partnership addresses Anritsu's business charter, which includes strong penetration into the military and government markets. Anritsu has implemented a business plan that will result in improved sales into these key market segments. The business plan includes developing test equipment for specific military and government applications, as well as improved sales and distribution. TestMart's marketing niche within the US government test-equipment marketplace will prove especially beneficial in Anritsu reaching its goals, according to Phil Bowen, vice president and general manager for Anritsu Americas Region.


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3G Delays Are Expected To Boost GPRS Revenue Potential

CAMBRIDGE, ENGLAND—Continuing delays in the launch of third-generation (3G) services by mobile operators across Western Europe will result in a much-wider window of opportunity for GPRS technology, according to a report from Analysys, a global adviser of telecoms, IT, and media.

The report, *Western European Mobile Forecasts and Analysis 2003-2008*, forecasts that revenue from GPRS subscribers will grow from EUR15 billion (approximately $17.4 billion US) in 2003 and peak at EUR73 billion (about $84.6 billion US) in 2006, before beginning its inevitable decline as customers move GPRS to UMTS.

"By 2005, 3G subscriber numbers in Western Europe will remain extremely small, with just over 20 million active mobile subscribers using a 3G service."

"Only Hutchinson 3G, Manx Telecom, and Mobilkom Austria have launched commercial 3G services in Europe by the end of September 2003," comments Ariel Dajes, co-author of the report. "As a result of the widespread delays in UMTS launches, by the end of 2003 the total number of 3G subscribers across Western Europe will be a mere 1.3 million."

Operators have cited financial and technical reasons for delaying the launch of their UMTS services, including difficulties in obtaining mast sites, problems in sourcing 3G handsets, and unproven demand for 3G services, says Analysys. However, the delays have provided a significant boost to the revenue potential of GPRS.

The report states that even by 2005, 3G subscriber numbers in Western Europe will remain extremely small, with just over 20 million active mobile subscribers using a 3G service. By 2005, Italy will remain the country with the most 3G subscribers in Western Europe, followed by the UK and Germany. However, Analysys forecasts that UMTS subscribers and revenues will start to escalate from 2006.

Ulrich L. Rohde Is Honored By The German Government

PATERSON, NJ—Dr. Ulrich L. Rohde has been appointed by the German government (Board of Supervisors) of the Innovation for High Performance (IHP) Microelektronics group within the Intitut fuer Microelektronik. Dr. Rohde is chairman of Synergy Microwave (Paterson, NJ), board member of the Ansoft Corp. (Pittsburgh, PA), and partner of the Munich, Germany-based global test-and-measurement manufacturer Rohde & Schwarz. Rohde, who holds a professorship for RF and microwave circuitry within the University of Cottbus, was awarded the honor by Dr. Helm (chairman of the board) during the July 14th meeting of the board of supervisors. Rohde will work with members of the IHP (Frankfurt-Oder, Germany), which is Germany's largest government-owned silicon-germanium (SiGe) foundry, on the development of next-generation, high-performance RF and microwave integrated circuits (ICs).

The IHP Advisory Board boasts some of the leading researchers from Germany and Switzerland, including Günter Zimmer of the Fraunhofer Institut fuer Microelektronische Schaltungen und Systeme (Duisburg, Germany), Dr. Ing. Jurgen Arndt of Atmel (Heilbron, Germany), Prof. Dr. Ignaz Eisele of the Institut fuer Physik der Fakultat fuer Elektroteknik und Informationstechnik der Universitat der Bundeswehr (Munich, Germany), and Prof. Dr. Christan Enz of CSEM (Neuchatel, Switzerland).

Kudos

LEXINGTON, MA—Two Raytheon Co. businesses in North Texas have attained Capability Maturity Model Integration (CMMI®) Level 5 certification for software engineering from the Software Engineering Institute (SEI).

CMMI Level 5 is the highest certification of software engineering excellence that can be achieved. CMMI levels are increasingly used by government agencies and contractors to evaluate the potential for organizations to produce quality products on time and within budget.

AUSTIN, TX—Dr. James Truchard, president, CEO, and co-founder of National Instruments Corp., was recently recognized for his achievements in engineering and science by his election as Foreign Member of the Royal Swedish Academy of Engineering Sciences. The organization showcases and rewards achievement in the fields of natural sciences, engineering, and economics. Its members include distinguished engineers and economists from around the world in business and industry, as well as education and public administration.

The academy recognized Truchard for the role he has played in technological advancement, particularly invention and introduction of NI LabVIEW, the award-winning graphical-development software invented in 1986 by Truchard and his colleague and NI co-founder, Jeff Kodosky. MRF

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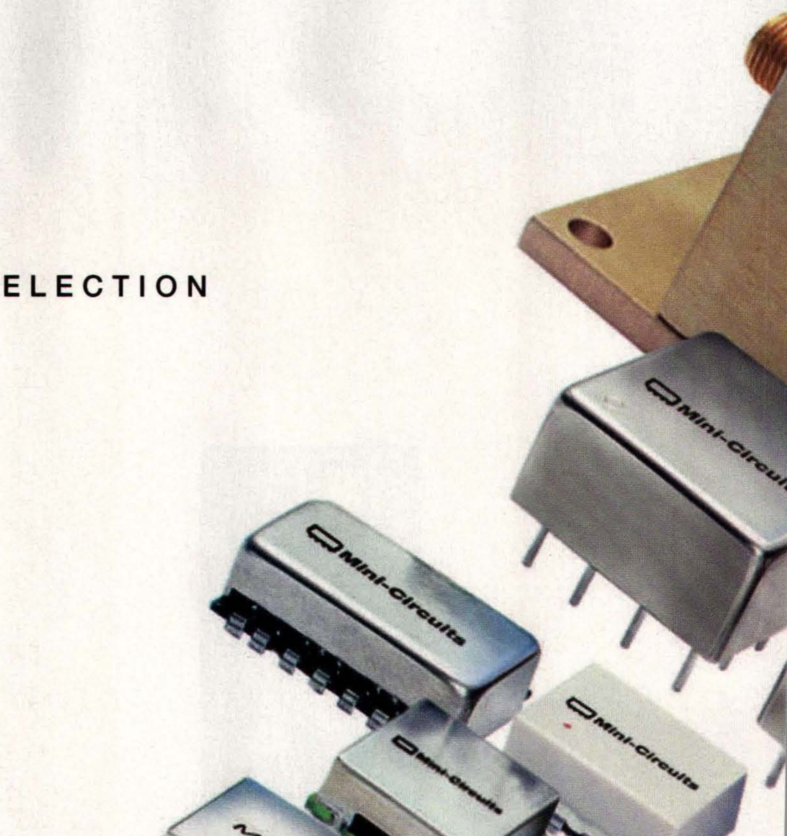

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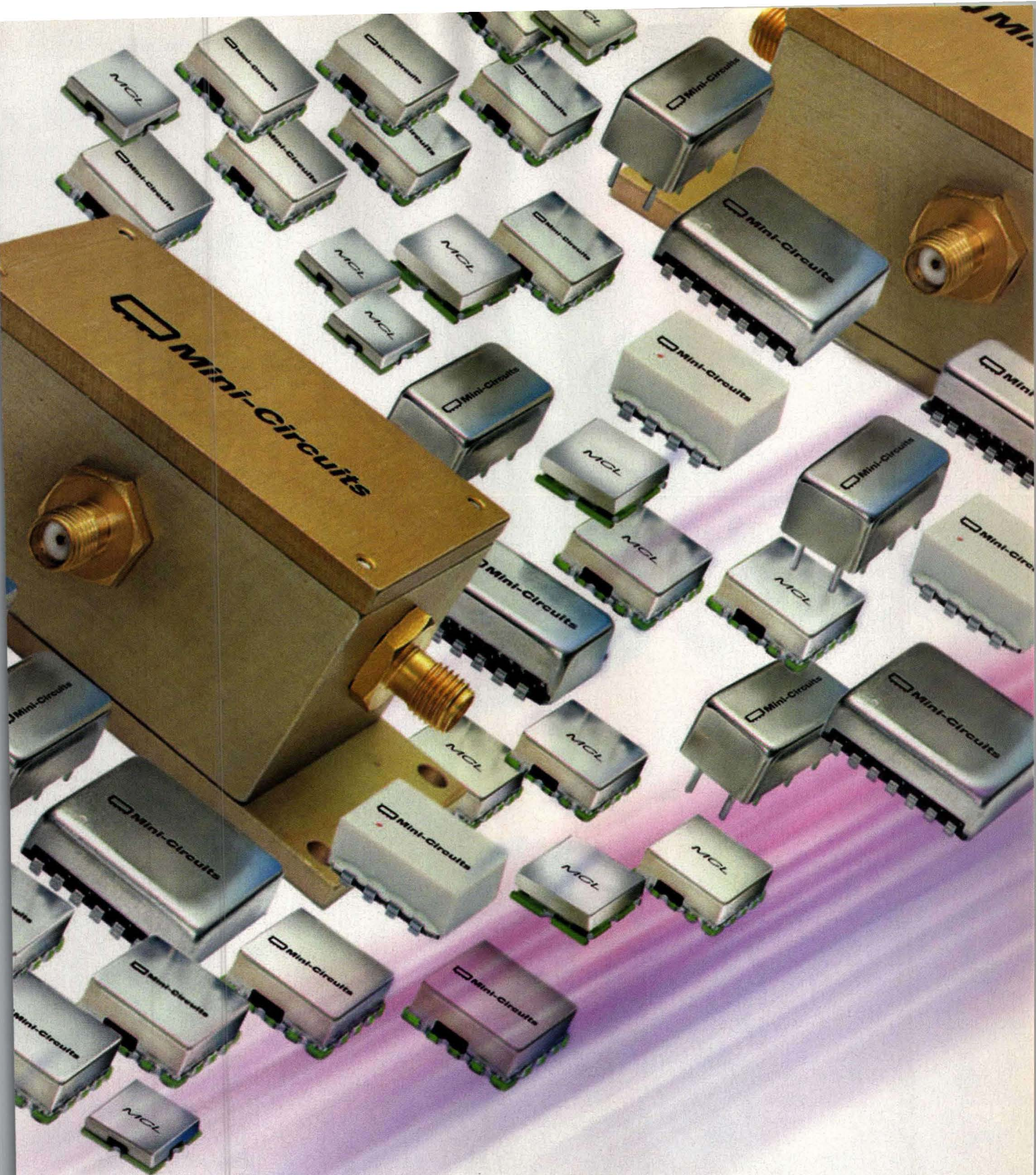

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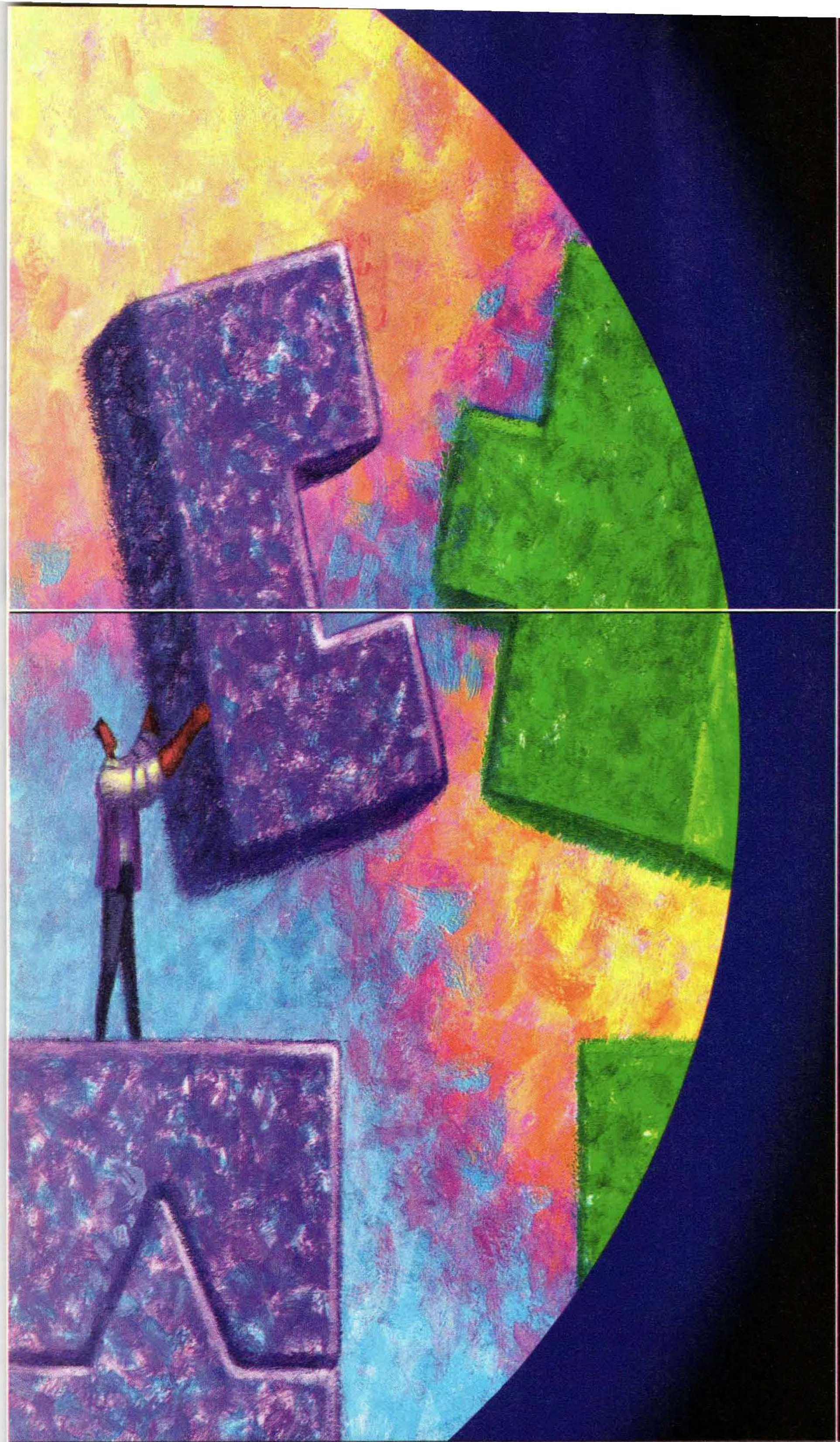

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Annual IEDM Heralds Device Developments

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JACK BROWNE
Publisher/Editor

Device technology progresses quickly, even in the eyes of those who track semiconductor advances. For those interested in the state of the art, there may be no better place to compare standards than the annual International Electron Devices Meeting (IEDM). Scheduled for December 8-10, 2003 in the Hilton Washington and Towers hotel (Washington, DC), the 49th Annual IEDM promises a wide cross section of leading semiconductor technologies, from logic and memory to RF power transistors and millimeter-wave integrated circuits (ICs).

For example, in a session on solid-state devices, Katsuyoshi Washio of Hitachi Ltd.'s Central Research Laboratory (Tokyo, Japan) will detail improvements in silicon-germanium heterojunction-bipolar-transistors (SiGe HBTs) and BiCMOS technologies. His presentation notes that the use of self-aligned fabrication processes along with thinning of the base width have enabled device developers to reduce parasitic device capacitances and resistances to achieve maximum frequency of oscillation for SiGe HBTs in excess of 250 GHz. Washio predicts that gate delays will reach a mere 3 ps in 2005, supporting the development of logic circuitry operating at 160 GHz.

Following Washio, B. Heinemann and co-workers from IHP (Frankfurt, Germany) will report on a 200-GHz complementary BiCMOS process with isolated SiGe:C PNP HBT devices. By using a highly tuned vertical doping profile, the isolated PNP transistors can be readily integrated into the CMOS process. Fabricated devices have shown current gain of 160 at a +2 VDC for an NPN HBT, with peak maximum frequency of oscillation in the range of 110 to 120 GHz.

In the first of several sessions on displays, sensors, and microelectromechanical systems (MEMS), Paul Baude and associates from the 3M Company (St. Paul, MN) presented results for organic-semiconductor-based radio-frequency-identification (RFID) transponders. The transponders feature pentacene-based thin-film circuitry, including a ring oscillator that, when activated, generates a clock signal which is buffered and used to modulate the RF signal. Amplitude modulation (AM) of a 4.079-MHz field is detected externally with a simple diode-based peak detector. The researchers accomplishment is the first reported demonstration of organic semiconductor technology without external rectification.

Following Baude's presentation, a fascinating student session by Josephine Lee and Vivek Subramanian from the Department of Electrical Engineering and Computer Sciences at the Universi-

ty of California at Berkeley explored the use of organic transistors fabricated on fabric, opening the way for the first electronic textile materials. The process employs 125-µm-diameter aluminum wire as the gate line, which can be woven directly into an electronic textile (e-textile). The fiber was encapsulated with a thin-layer gate dielectric, 60-nm pentacene channel material was evaporated, and the fiber was masked with orthogonal over-woven 50-µm-diameter wires, serving as channel masks. Then 100-nm gold was evaporated to form source/drain contacts. Upon removal of the over-woven fibers, arrays of transistors resulted, with transistors formed at every intersection of the fibers. The devices, which are similar to conventional pentacene thin-film transistors (TFTs), exhibit well-behaved electrical characteristics with gate mobility on the order of 0.05 cm^2/V-s.

In the first of several sessions on quantum electronics and compound semiconductors, Sung-Yung Chung and associates from Ohio State University (Columbus, OH), the US Naval Research Laboratory (Washington, DC), the University of California at Riverside (Riverside, CA), and the Rochester Institute of Technology (Rochester, NY) reported on the first monolithic vertical integration of a Si/SiGe HBT with a Si-based resonant interband tunnel diode (RITD). The device acts as a logic latch with adjustable peak-to-valley current ratios.

In a session on RF power devices and passive components, Helmut Brech and co-workers from the RF and DSP Infrastructure Division of the Semiconductor Products Sector of Motorola (Tempe, AZ) reported on record numbers for efficiency and gain of power transistors used in wideband-code-division-multiple-access (WCDMA) communications systems at 2.1 GHz. The sixth-generation lateral DMOS (LDMOS) transistor features cutoff frequency and maximum frequency of oscillation of 8 and 18 GHz, respectively, along with small-signal gain of 25.5 dB. The gate length and oxide thickness were both reduced to improve the high-frequency response, although drain optimization did not compromise reliability with projected quiescent current drift of less than 4 percent extrapolated over 20 years. When used in the 2.1-GHz band with a two-carrier WCDMA signal, the device achieved 29-percent drain efficiency with 20 W output power and third-order intercept point of –37 dBc, while maintaining power gain at 16.5 dB. Under other test conditions, power-added efficiency (PAE) of 61 percent was achieved with output power of more than 100 W.

Also in the RF power device session, Jonghae Kim and associates from IBM's Semiconductor Research and Develop-

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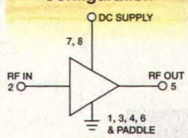

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MNA-5	0.5-2.5	5.0 2.8	21.9 20.5	12.2 10.1	1.60
MNA-6	0.5-2.5	5.0 2.8	23.6 21.2	18.0 14.1	2.25
MNA-7	1.5-5.9	5.0 2.8	15.9 13.7	15.6 12.7	2.25
VNA-21	0.5-2.5	5.0 2.8	13.5 12.3	8.5 7.0	1.80
VNA-22	0.5-2.5	5.0 2.8	13.8 12.6	17.0 14.0	2.20
VNA-23	0.5-2.5	5.0 2.8	18.3 17.1	10.0 8.5	1.90
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ment Center (Hopewell Junction, NY) and the Department of Electronics at Carleton University (Ottawa, Ontario, Canada) detailed highly manufacturable 40-to-50-GHz voltage-controlled oscillators (VCOs) fabricated in a 120-nm system-on-a-chip (SoC) technology. The tunable oscillators are designed to provide as much as 15-percent frequency tuning range in embedded RF circuits at frequencies to 50 GHz. The total power dissipation is 15 mW at +1.8 VDC and the phase noise offset 1 MHz from the carrier is –90.2 dBc/Hz.

In the RF power device session, Albert Chin and fellow researchers from the National Chiao Tung University (Hsinchu, Taiwan), the United Microelectronics Corp. (Hsinchu, Taiwan), and the Institute of Nuclear Energy Research (Taoyuan, Taiwan) detailed how it was possible to produce near-ideal passive components on silicon substrates at frequencies through 100 GHz with the help of electromagnetic (EM) computer modeling tools. Using the IE3D EM design tool from Zeland Software (Fremont, CA), the researchers succeeded in fabricating a variety of components, including coplanar-waveguide (CPW) filters at 91 GHz with maximum transmission loss of 1.6 dB.

In the first of several sessions on quantum electronics (with a focus on wide bandgap devices), Y. Ando and co-workers from the Photonic and Wireless Devices Research Laboratories of NEC Corp. (Otsu, Japan) presented their latest data on recessed-gate AlGaN/GaN heterojunction field-plate FETs with tremendous potential for high-power amplification. At 2 GHz and 66 V, these recessed-gate devices demonstrated a CW saturated output power of 12 W (power density of 12 W/mm device periphery) with linear gain of 21.2 dB and PAE of 48.8 percent.

R. Quay and associates from the Fraunhofer Institute of Applied Solid-State Physics (Freiburg, Germany) detailed AlGaN high-electron-mobility transistors (HEMTs) fabricated on silicon-carbide (SiC) substrates for applications at V-band (60 GHz) frequencies. The researchers achieved +13.9 dBm output power with 4 dB gain at 60 GHz.

Finally, Walid Hafez and Milton Feng from the Department of Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign (Urbana, IL) described what must be done for the fabrication of indium-phosphide (InP) HBTs with cutoff frequencies as high as 502 GHz using molecular-beam-epitaxial (MBE) wafers. For more information on the upcoming IEDM, contact Conference Manager Phyllis Mahoney, Widerkehr & Associates, 16220 S. Frederick Ave., Gaithersburg, MD 20877; (301) 527-0900 ext. 103, e-mail: phyllism@widerkehr.com. MRF

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CNG-1700/2400	1700MHz - 2400MHz
CNG-2200/2700	2200MHz - 2700MHz
CNG-800/2700	800MHz - 2700MHz

Broadband Noise (WGN) Series	
Model	*Frequency range*
WGN-1/200	1MHz - 200MHz
WGN-5/1005	5MHz - 1005MHz
WGN-800/1000	800MHz - 1000MHz
WGN-870/1750	870MHz - 1750MHz
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7821B
7821C
2.4mm
7921A
7921B
7921C
2.92mm
8714A1
8714B1
8714C1
3.5mm
8021A2
8021B2
8021C2
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Email: maury@maurymw.com

PRBS Source Supports Data Rates To 12 Gb/s

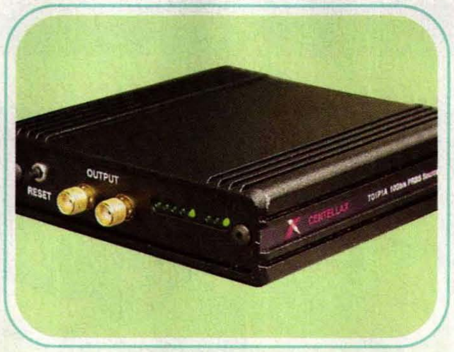
DESIGNED FOR USE as a source for testing high-speed components and systems such as those used in OC-192 optical communications networks operating at data rates from DC to 12.5 Gb/s, the model TG31P1A miniature pseudorandom bit-stream (PRBS) generator supports pattern lengths of 2^7, 2^{10}, 2^{15}, 2^{23}, and 2^{31}. It also supports mark/space density ratios of 1/8, 1/4, and 1/2, and features output jitter of less than 1 ps root mean square (RMS). Measuring 3.5 × 3.5 × 1 in. (8.89 × 8.89 × 2.54 cm), the source can be placed directly adjacent to a device under test (DUT) to facilitate measurements even on crowded test benches.

Centellax, Inc., 451 Aviation Blvd., Suite 101, Santa Rosa, CA 95403-1069; (707) 568-5900, FAX: (707) 568-7647, e-mail: sales@centellax.com, Internet: www.centellax.com.

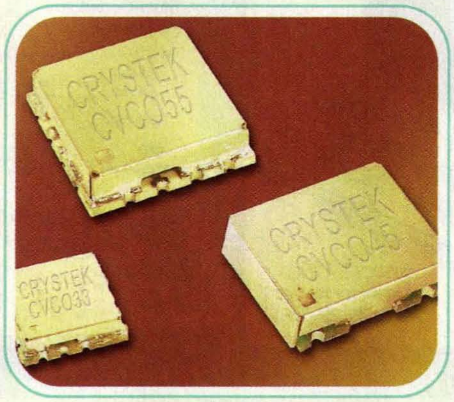
VCOs Tune From 50 MHz To 3.5 GHz

HOUSED IN COMPACT, surface-mount packages, a line of voltage-controlled oscillators (VCOs) offers stable output frequencies in bands from 50 MHz to 3.5 GHz. The CVC033, CVC045, and CVC055 families of oscillators feature tuning ranges of 50 to 2000 MHz, 50 to 2000 MHz, and 50 to 3500 MHz, respectively, operate with typical tuning voltages of 0 to +5 VDC. For narrowband (tuning ranges to 900 MHz) applications, the typical phase noise is –110 dBc/Hz offset 10 kHz from the carrier. For wideband (tuning ranges approaching 3.5 GHz in the CBC055 family) applications, the phase noise is typically –105 dBc/Hz offset 10 kHz from the carrier. The CVC033 oscillators measure 7.62 × 7.62 × 2.00 mm, the CVC045 oscillators measure 10.16 × 12.60 × 4.20 mm, and the CVC055 oscillators measure 12.70 × 12.70 × 3.60 mm.

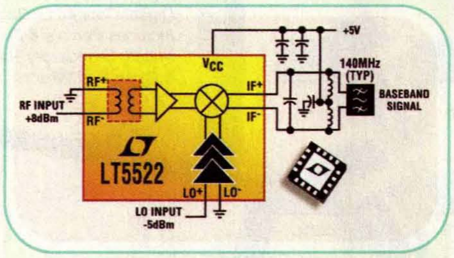
Crystek Crystals Corp., 12730 Commonwealth Dr., Fort Myers, FL 33913; (800) 237-3061, (239) 561-3311, FAX: (239) 561-1025, e-mail: salesdept@crystek.com, Internet: www.crystek.com.



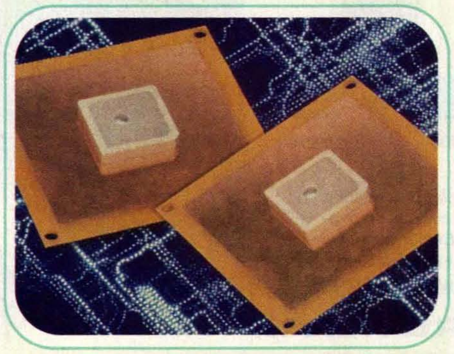
CENTELLAX'S MODEL TG31P1A PRBS GENERATOR



CRYSTEK CRYSTALS CORP. VCOS



LINEAR TECHNOLOGY CORP.'S MODEL LT5522 ACTIVE MIXER



SPECTRUM FSY MICROWAVE'S PATCH ANTENNA

Active Downconverter Mixer Reaches 2.7 GHz

MIXER LOSS CAN be neglected when using the model LT5522 active mixer. The downconverting mixer accepts input signals from 600 to 2700 MHz, and operates with local-oscillator (LO) signals from 400 to 2700 MHz to yield an intermediate-frequency (IF) range of 0.1 to 1000 MHz. Conversion loss is typically less than 0.5 dB and a worst-case value of 0.7 dB with an RF input of 2450 MHz. The RF-to-LO isolation is better than 45 dB from 50 to 2700 MHz. The mixer features an on-chip RF input transformer with a differential LO buffer amplifier driving a double-balanced mixer to facilitate balanced signal connections. The model LT5522 active donconversion mixer is supplied in a 16-lead 4 × 4-mm QFN package. P&A: $5.20 each (1000 qty.); stock.

Linear Technology Corp., 1630 McCarthy Blvd., Milpitas, CA 95035-7417; (408) 432-1900, FAX: (408) 434-6441, Internet: www.linear.com

Patch Antenna Provides SENS Reception

A LOW-COST patch antenna has been developed for Sensor Enabled Notification System (SENS) applications in which reliable data transfer can be accomplished via satellite. The SENS antenna facilitates clear reception anywhere on Earth, and has been optimized for use with the Globalstar™ satellite constellation. The antenna features a center frequency of 1615 ± 5 MHz with 3 dBic minimum gain at zenith. The antenna operates with left-hand circular polarization and features a half-power beamwidth of 100 deg. and maximum VSWR of 2.0:1 for a 25-MHz bandwidth. The variation in directivity is less than 5 dB when measured from the zenith to a 25-deg. elevation angle. P&A: $5 to $15 (depending upon package); 1 to 4 wks.

Spectrum FSY Microwave, 6798 Oak Hall Lane, Columbia, MD 21045; (410) 381-5700, FAX: (410) 381-0140, e-mail: briddell@specwave.com, Internet: www.spectrumcontrol.com.

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Phone: (973) 881-8800 Fax: (973) 881-8361
E-mail: sales@synergymwave.com
Website: www.synergymwave.com
SYNERGY® MICROWAVE CORPORATION

Fairchild Buys Raytheon's RF Unit

FAIRCHILD SEMICONDUCTOR, a supplier of products that optimize system power for multiple end markets, announced that it has purchased the commercial unit of the RF Components Division of the Raytheon Co. The purchase provides Fairchild with an immediate entry into the advanced RF market for applications that include wireless LANs (WLANs) and handset power amplifiers (PAs). The agreement also adds gallium-arsenide millimeter-wave integrated circuits (GaAs MMICs) to Fairchild's portfolio of building-block components that power multiple-end market products. The business will report to Fairchild's Power Discrete Group, led by Dr. Izak Bencuya, executive vice president and general manager.

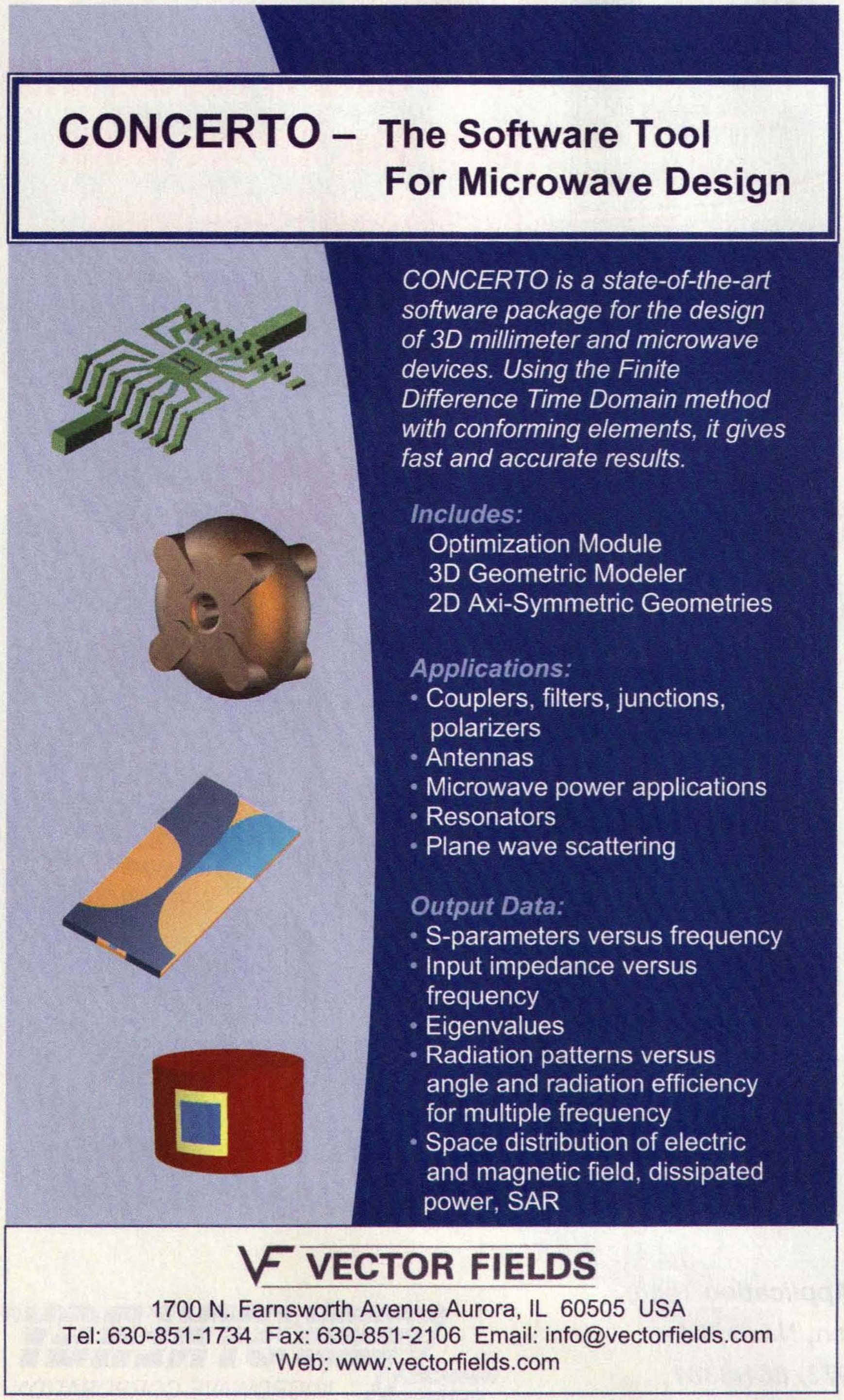
"The addition of RF power amplifiers to our current power products offering strengthens Fairchild's presence in the wireless-communications market, while enabling expanded design opportunities in the areas of wireless LANs and headsets," comments Bencuya. "The total market size for gallium-arsenide power amps is projected by Strategy Analytics to grow to between \$770 million and \$1.2 billion by 2006, with a compound annual growth rate of 16 percent, adding another dimension to Fairchild's Power Franchise. We expect this business should ramp to revenues of more than \$5 million per quarter towards the latter half of 2004."

Fairchild has also acquired Raytheon's foundry partnership agreement for the supply of GaAs wafers and an equity stake in WIN Semiconductor, as well as access to foundry and support services at Raytheon's Andover, MA facility. As part of the asset purchase agreement and transfer of intellectual property, more than 30 Raytheon designers, test engineers, and business-development employees will join Fairchild.

Russ Wagner, former Raytheon RF Components vice president of business development, will lead the group.

"We look forward to leveraging new opportunities in product development and customer support as part of Fairchild's Power Discrete Group," comments Wagner.

Financial details of the agreement were not disclosed. MRF



The system designer's choice for nearly thirty years

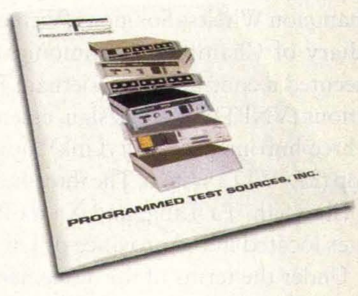
PTS Synthesizers are found in more test systems than any other synthesizer on the market.

What engineers like most about PTS is our ability to provide the right performance at the right price. At PTS, we believe there is no such thing as a "one size fits all" solution. As a result, we've built a loyal following, and have the largest installed base in the industry today. For instance, maybe you need coverage to 3200 MHz, but don't need manual control. Or maybe 1 GHz will do, but you'd like to add a programmable step attenuator. No problem. Operating to 6 GHz these days? We have you covered. Our PTS 6400 blends direct analog and digital frequency synthesis techniques to offer high spectral purity and fast frequency switching speed from 1 to 6400 MHz.

Our list of standard features and options includes: BCD or GPIB control; DDS with phase continuous switching; digital phase rotation; output power up to +13 dBm; phase noise characteristics as good as –132 dBc/Hz (100 MHz, 20 KHz offset); and switching as fast as 1 µs.

We back every synthesizer with an industry leading 3-year warranty.

At PTS, we adhere to conservative de-rating practices, keep power consumption and internal heat build-up to an absolute minimum, and subject finished systems to rigorous temperature cycling and electrical testing. The result? Proven 25,000 hour MTBF figures, and the confidence to offer you the best warranty in the business.



Choose from a vast selection of reasonably priced synthesizers to find the one that's right for you.

Our synthesizer line spans 16 models starting with the PTS x10 priced at $2,250. It features 1 Hz resolution and DDS phase continuous switching. Even our top-of-the-line PTS 6400 is just $15,000. It features 3-20 µs switching and phase noise of –122 dBc/Hz (1 GHz, 20 KHz offset).

Imagine, outstanding performance and the best warranty—all at a great price. PTS. The system designer's choice.

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CONTRACTS

Lockheed Martin Commercial Space Systems—Has been awarded a contract to build an A2100 geosynchronous satellite for EchoStar X, will provide distribution of direct-to-home broadcast services across the continental US, Alaska, and Hawaii following its scheduled launch in the third quarter of 2005. Financial terms were not disclosed.

Herley Industries, Inc.—Announced that its Power Amplifier Systems division has received a $2.25 million contract to supply high-power transmitter hardware to upgrade communication systems for a major OEM. Herley expects to complete delivery of the hardware over the next 12 months.

Lucent Technologies—Was awarded a $20 million contract by CODETEL, the Dominican Republic's primary telecommunications operator. Lucent will provide equipment, software, and services that will increase the capability and coverage of CODETEL's existing CDMA mobile network and enable it to support third-generation (3G) CDMA2000® 1X voice and data services.

CHAMPION Communication Services, Inc.—Announced that Champion Wireless Solutions (Vietnam) Ltd., an indirect subsidiary of Champion Communication Services, Inc., has executed a contract with Vietnam Post and Telecommunications (VNPT) for the design, assembly, and installation of a three-hub integrated SkyLink™ low-density wireless-local-loop (LD-WLL) system. The three-hub system will be installed in Giao San, Ta Tang, and Xa da Phin. All are remote villages located in the province of Lai Chau, Vietnam.

Under the terms of the agreement, the full details of the contract cannot be made public. The sale price of the three-hub system is between $175,000 and $225,000.

FRESH STARTS

Olympus Partnership Development Group (PDG)—Announced that Olympus Optical Co. Ltd. of Tokyo, Japan has formed a new MEMS Technology Division, which will unify all previous MEMS activities including R&D and MEMS foundry services. Although Olympus has been active in research and development (R&D) of MEMS and MEMS-related products for over ten years, the reorganization enables the Olympus MEMS technology and foundry capabilities to be greatly improved and expanded. In addition, the facilities for MEMS assembly will be increased by 30 percent and R&D given increased priority and focus.

Cascade Microtech—Has opened a new office in Singapore. Cascade Microtech Singapore is responsible for direct sales, service, and support of products for Cascade's Engineering Product Division (EPD) in Singapore and Malaysia. These products include wafer probes, test stations, and related accessories.

The office address is: Cascade Microtech Singapore, 51 Science Park Rd., #04-11, The Aries Singapore Science Park II, Singapore 117586.

Taconic—Has purchased Teradyne's laminate facility in La Verne, CA. The former Synthane Taylor plant will be used to manufacture TacPreg® prepregs and TacLam® laminates for high-layer-count high-speed digital and microwave applications.

ANADIGICS, Inc.—Announced the opening of a new application center in Taipei, Taiwan to support growing customer demand for ANADIGICS' WLAN, CDMA, and GSM RF products. The facility's staff of highly experienced application engineers will provide local applications support to ANADIGICS' OEM and ODM customer base by facilitating the customer RF design process and shortening time to market for wireless and broadband end products.

RFMW Ltd.—Has signed a North American distribution agreement with Skyworks Solutions, Inc. Skyworks is an RF/microwave semiconductor company providing subsystems, modules, building blocks, and discrete components to a worldwide customer base.

NDK Crystal, Inc. and NDK America, Inc.—Commemorated the official opening of their new Belvidere, IL facility. This 55,000-sq.-ft. facility will house the executive and sales functions for North and South America. There is also a design center and warehouse to support all customers in the Americas. The manufacturing side features an 80-ft. tower to house eight new autoclaves for producing synthetic quartz crystals.

DALSA Semiconductor and Discera, Inc.—Announced that Discera has selected DALSA as its high-volume manufacturer for a suite of RF MEMS integrated micro-components for frequency and timing applications, including silicon technology seen as a replacement for quartz crystals and SAW filters.

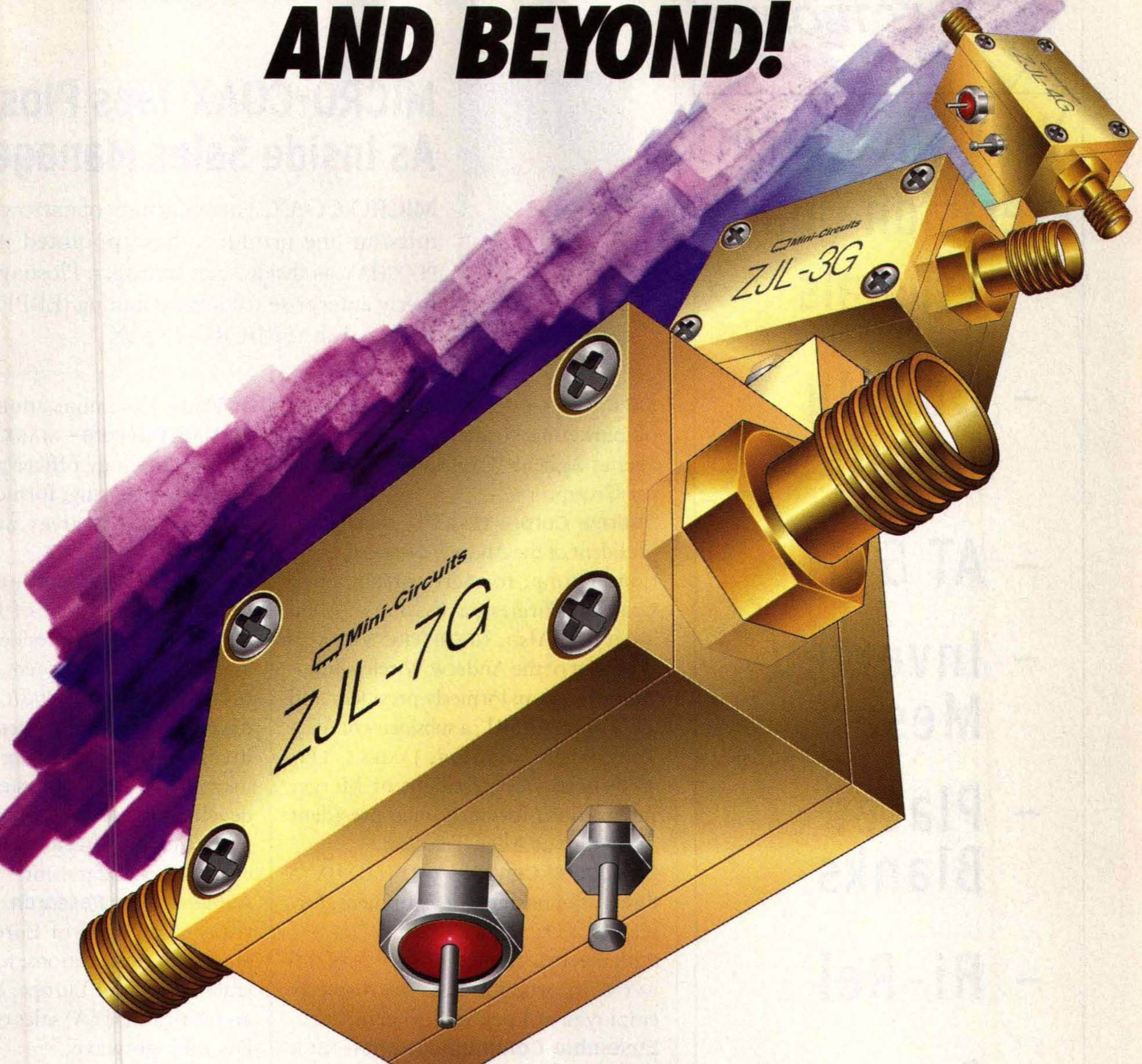
M-tron Industries, Inc.—Appointed A4S to represent M-tron's entire line of frequency-control products in Belgium and Luxemburg. A4S has their Sales office in Antwerp, Belgium.

BroadWave Technologies, Inc.—Announced new representative appointments for their line of coaxial passive components and custom test systems. Southern Marketing Associates of Longwood, FL will cover Florida, Georgia, Alabama, Tennessee, and North/South Carolina. Bouillon Technology Solutions of Plano, TX will provide coverage for Texas, Oklahoma, Arkansas, and Louisiana. Advanced Technology Sales of Los Altos, CA is responsible for Northern California and Northern Nevada.

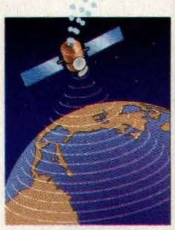
I.F. Engineering Corp.—Has relocated to a larger facility to accommodate significantly increased engineering and manufacturing demands. IFE's new contact information is: 40 Parker Rd., Fabyan, CT 06255; (860) 935-0280, FAX: (860) 935-0283, e-mail: sales@ifengineering.com, Internet: www.ifengineering.com.

Andrew Corp.—Announced its membership in the Wi-Fi® Alliance, a not-for-profit international organization that certifies the interoperability of IEEE 802.11 products. MRF

THE GLOBAL SOLUTION... AND BEYOND!



10MHz to 7GHz AMPLIFIERS from $99.95 (1-9 qty.)



From amateur radio to cellular to satellite applications, with medium output power up to 17dBm, Mini-Circuits versatile ZJL and ZKL connectorized amplifiers offer the broad range of choices designers demand for achieving high system performance goals. Ultra-wideband models deliver **gain ranging from 9 to 40dB** and IP3 up to +32dBm. But beyond the performance and reliability built into these miniature 12V amplifiers lies another important feature, the low price...from only $99.95! Call now for fast delivery.

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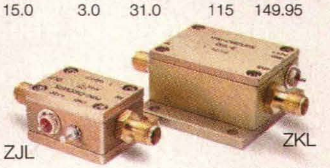
SPECIFICATIONS

Model	Freq (MHz)	Gain (typ) Midband (dB)	Gain (typ) Flat (±dB)	Max. P_{out}[1] (dBm)	Dynamic Range (Typ @2GHz[2]) NF(dB)	Dynamic Range (Typ @2GHz[2]) IP3(dBm)	I(mA)[3]	Price $ea. (1-9)
ZJL-5G	20-5000	9.0	±0.55	15.0	8.5	32.0	80	129.95
ZJL-7G	20-7000	10.0	±1.0	8.0	5.0	24.0	50	99.95
ZJL-4G	20-4000	12.4	±0.25	13.5	5.5	30.5	75	129.95
ZJL-6G	20-6000	13.0	±1.6	9.0	4.5	24.0	50	114.95
ZJL-4HG	20-4000	17.0	±1.5	15.0	4.5	30.5	75	129.95
ZJL-3G	20-3000	19.0	±2.2	8.0	3.8	22.0	45	114.95
ZKL-2R7	10-2700	24.0	±0.7	13.0	5.0	30.0	120	149.95
ZKL-2R5	10-2500	30.0	±1.5	15.0	5.0	31.0	120	149.95
ZKL-2	10-2000	33.5	±1.0	15.0	4.0	31.0	120	149.95
ZKL-1R5	10-1500	40.0	±1.2	15.0	3.0	31.0	115	149.95

NOTES:
1. Typical at 1dB compression.
2. ZKL dynamic range specified at 1GHz.
3. All units at 12V DC.



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PLOSHAY

MICRO-COAX Taps Ploshay As Inside Sales Manager

MICRO-COAX, a manufacturer of microwave transmission-line products, has appointed JEANNE E. PLOSHAY as inside sales manager. Ploshay was formerly enterprise resource planning (ERP) and business analyst at MICRO-COAX.

EiC Corp.—PETER SAHJANI to director of marketing; formerly product manager at Agilent Wireless Semiconductor Group.

Andrew Corp.—TERRY N. GARNER to president of the Andrew Network Solutions Group; formerly president of Grayson Wireless, a division of Allen Telecom. Also, GIANPIERO VILLA to president of the Andrew Wireless Innovations Group; formerly president and CEO of Forem SRL, a subsidiary of Allen Telecom. In addition, JAMES L. LEPORTE III to vice president of Merger Integration; formerly vice president of finance at Allen Telecom.

Broadband Central—TALI HALEUA to director of business development; formerly CEO.

Park Electrochemical Corp.—DONALD PAYNE to product director; formerly employed at Lockheed Martin Corp.

Ensemble Communications—NICK PIANIM to vice president of corporate development; formerly CEO of iAsiaWorks. Also, WARREN RODDY to vice president of global sales; formerly senior vice president for worldwide sales at Pluris. In addition, KEVIN RYAN to vice president of marketing and business development; formerly vice president of marketing and business development at Network Photonics.

TRL Technology Ltd.—KEN JARVIS to international sales manager for the Government Systems Business Unit; formerly employed in international military sales.

HYPRES, Inc.—FELIX J. BOCCADORO to vice president for business development and legislative affairs; formerly director of tactical communications business development and legislative affairs at Thales Communications, Inc.

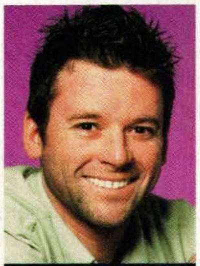
Myriad Telecom—MARK RYLAND to chief technology officer and director of patent licensing; formerly director of standards strategy at Microsoft Corp.

Cascade Microtech, Inc.—ERIC I. BLACHNO to vice president of finance and CFO; formerly vice president of finance and CFO with Luminent, Inc.

Modelithics, Inc.—PAUL B. FIRTH to director of sales and marketing; formerly involved in engineering of aircraft microwave navigation systems, software development of data communications products, high-tech marketing, and executive management.

Applied Wave Research, Inc.—CHRIS PARIS to director of European sales and support operations; formerly general manager for Europe, Middle East, and Africa (EMEA) sales operations at Digital Lightwave.

Link Microtek Ltd.—JOHN PEPPER to IT and broadband support engineer; formerly IT administrator/system engineer at Surtech.

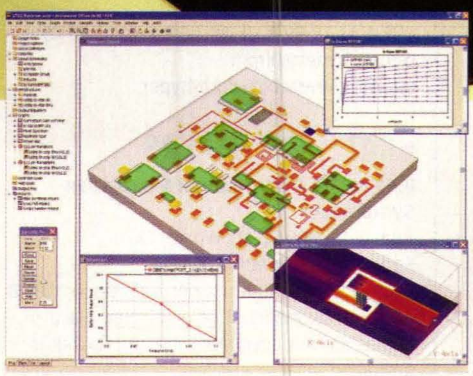


PEPPER

GILLERN

Rogers Corp.—FRANK GILLERN to vice president of Rogers' Advanced Circuit Materials Division (ACMD); formerly vice president of operations for Durel Corp., a joint venture of 3M and the Rogers Corp. MRF

AWR



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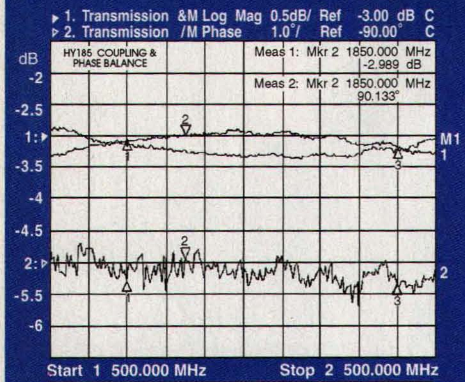
HY185	1700-2400	0.15dB	0.30dB	-20dB

HY185 TYP. PERFORMANCE (min)



1: Mkr (MHz)	dB	2: Mkr (MHz)	Deg
1: 1700.00	-3.061	1: 1700.00	89.397
2> 1850.00	-2.989	2> 1850.00	90.133
3: 2400.00	-3.186	3: 2400.00	89.359

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Wireless Data Ecosystem: Value Propositions For Messaging & Content Applications
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The Westin St. Francis
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Internet: www.srinstitute.com/cg103

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Remote Sensing for Earth Science Applications
December 16-19 (Washington, DC/Maryland)
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For further information, contact:
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Internet: www.aticourses.com/schedule.htm

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NIST, M.S. 813.01
325 Broadway
Boulder, CO 80305
(303) 497-5490, FAX: (303) 497-3970
e-mail: dwalker@boulder.nist.gov
Internet: www.arftg.com

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(626) 395-4043, FAX: (626) 795-7174
e-mail: execedu@caltech.edu
Internet: www.irc.caltech.edu

►MEETINGS

62nd ARFTG Microwave Measurement Conference: Differential Measurements
December 2-5 (Boulder, CO)
Hotel Boulderado
Internet: www.arftg.com

International Radar Symposium India (IRSI-2003)
December 2-5 (Bangalore, India)
Hotel Grand Ashok
Internet: www.radarindia.com

Interconnection & Access Conference
December 8-10 (Washington, DC)
Fairmont Hotel
For further information, contact:
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11300 Rockville Pike, Suite 1100
Rockville, MD 20852
(888) ASK-CCMI
Internet: www.ccmi.com/conferences/interconnection

Digital Video Expo West
December 9-12 (Los Angeles, CA)
Los Angeles Convention Center
Internet: www.dvexpo.com/west

2003 International Semiconductor Device Research Symposium
December 10-12 (Washington, DC)
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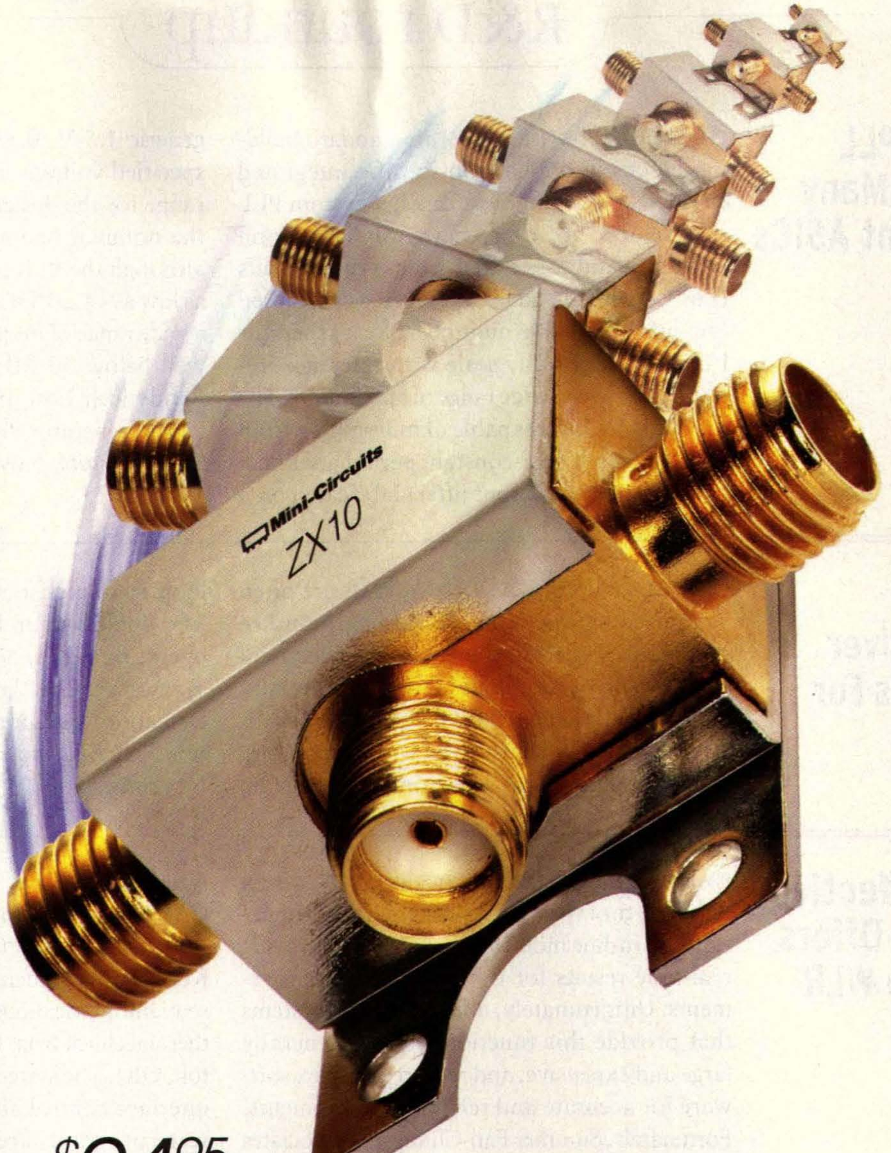

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Single PLL Serves Many Different ASICs

PHASE-LOCKED LOOPS (PLLS) are standard building blocks in application-specific integrated circuits (ASICs). In most cases, a custom PLL is developed for every new ASIC. But John Maneatis and associated from True Circuits (Los Gatos, CA) have developed a self-biased low-jitter 1-to-4096 multiplier clock generator PLL that can readily scale with reference frequency to cover a wide range of applications.The new PLL design is capable of multiplying from 1 to 4096 with near-constant period jitter (less than 1.7 percent output jitter) fabricated on a generic 1.5-V, 0.13-µm CMOS process. The specified voltage-controlled-oscillator (VCO) range for the design is 30 to 650 MHz, while the nominal operating voltage is +1.5 VDC although the PLL could operate with voltages as low as +1.2 VDC. Because the VCO supports a wide range of frequencies, the PLL can be used well below 30 MHz. See "Self-Biased High-Bandwidth Low-Jitter 1-to-4096 Multiplier Clock Generator PLL," *IEEE Journal of Solid-State Circuits,* November 2003, Vol. 38, No. 11, p. 1795.

Optical Transceiver Corrects For Jitter

OPTICAL COMMUNICATIONS SYSTEMS are often victimized by clock jitter. But Bong-Joon Lee and associates from the School of Electrical Engineering of the Seoul National University (Seoul, South Korea) have developed a 2.5-to-10-Gb/s CMOS transceiver with alternating edge-sampling phase detection for stabilizing loop characteristics even with varying jitter. The dual-loop architecture supports a wide operating range. See "A 2.5-10 Gb/s CMOS Transceiver With Alternating Edge-Sampling Phase Detection for Loop Characteristic Stabilization," *IEEE Journal of Solid-State Circuits,* November 2003, Vol. 38, No. 11, p. 1821.

Cost-Effective System Offers Flexible WLR Testing

WAFER-LEVEL RELIABILITY (WLR) TESTING is an essential tool for process reliability qualification and in-line monitoring since it can provide real-time results for timely process improvements. Unfortunately, automated test systems that provide this functionality are generally large and expensive, and require complex software for accurate and reliable measurements. Fortunately, Summer Fan-Chung and associates from The Research Institute of Micro/Nanometer Science and Technology of Shanghai Jiao-Tong University (Shanghai, China) and Semiconductor Manufacturing International Corporation (Shanghai, China) have developed a cost-effective system that provides wafer-level reliability testing for a fraction of the cost of commercial measurement solutions. The test system includes a model 4156C parameter analyzer from Agilent Technologies (Santa Rosa, CA), a pulse generator (a model 41501B from Agilent), a model 708A switching matrix from Keithley Instruments (Cleveland, OH), and a semiautomatic model 12751 wafer prober with thermal chuck from Cascade Microtech (Beaverton, OR). The system also includes software for interface control and data analysis. The software programs are developed internally for ease of maintenance. The wafer prober features a wide temperature test range of –55° to +200°C. The modular test system, with algorithms written in Visual Basic, can be readily updated for changing needs. See "A Cost-Effective Wafer-Level Reliability Test System for Integrated Circuit Makers," *IEEE Transactions on Instrumentation and Measurement,* October 2003, Vol. 52, No. 5, p. 1458.

Design An Efficient Miniaturized UHF Planar Antenna

ARCHITECTURAL ANTENNA DESIGN is of increasing interest for mobile military communications applications where low visibility and high mobility are critical. Slot radiating elements are well suited for this application since they are compact, with a planar geometry, and are capable of transmitting vertical polarization when placed nearly horizontally. Slot antennas can also easily be excited by a microstrip line and can be matched to an arbitrary line impedance simply by moving the feed point along the slot. In using this geometry for the design miniature mobile antennas, Kamal Sarabandi and Reza Azadegan of the Radiation Laboratory in the Department of Electrical Engineering and Computer Science at the University of Michigan (Ann Arbor, MI) fabricated designs as small as 0.12 wavelength on a side (with quarter-wave resonant slots) but capable of 0.5 dBi gain at UHF when fabricated on FR4 substrate, which has a loss tangent of about 0.01. See "Design of an Efficient Miniaturized UHF Planar Antenna," *IEEE Transactions on Antennas and Propagation,* June 2003, Vol. 51, No. 6, p. 1270.

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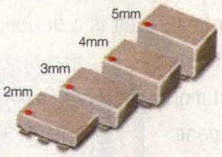

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ADEX-10L	+4	10-1000	7.2	60	16	3	2.95
ADE-1	+7	0.5-500	5.0	55	15	4	1.99▲
ADE-1ASK	+7	2-600	5.3	50	16	3	3.95
ADE-2	+7	5-1000	6.67	47	20	3	1.99▲
ADE-2ASK	+7	1-1000	5.4	45	12	3	4.25
ADE-6	+7	0.05-250	4.6	40	10	5	4.95
ADEX-10	+7	10-1000	6.8	60	16	3	2.95
ADE-12	+7	50-1000	7.0	35	17	2	2.95
ADE-4	+7	200-1000	6.8	53	15	3	4.25
ADE-14	+7	800-1000	7.4	32	17	2	3.25
ADE-901	+7	800-1000	5.9	32	13	3	2.95
ADE-5	+7	5-1500	6.6	40	15	3	3.45
ADE-5X	+7	5-1500	6.2	33	8	3	2.95
ADE-13	+7	50-1600	8.1	40	11	2	3.10
ADE-11X	+7	10-2000	7.1	36	9	3	1.99▲
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ADE-3G	+7	2300-2700	5.6	36	13	3	3.45
ADE-28	+7	1500-2800	5.1	30	8	3	5.95
ADE-30	+7	200-3000	4.5	35	14	3	6.95
ADE-32	+7	2500-3200	5.4	29	15	3	6.95
ADE-35	+7	1600-3500	6.3	25	11	3	4.95
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ADE-42MH	+13	5-4200	7.5	29	17	3	14.95
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ADE-1HW	+17	5-750	6.0	48	26	3	6.45
ADEX-10H	+17	10-1000	7.0	55	22	3	3.45
ADE-10H	+17	400-1000	7.0	39	30	3	7.95
ADE-12H	+17	500-1200	6.7	34	28	3	8.95
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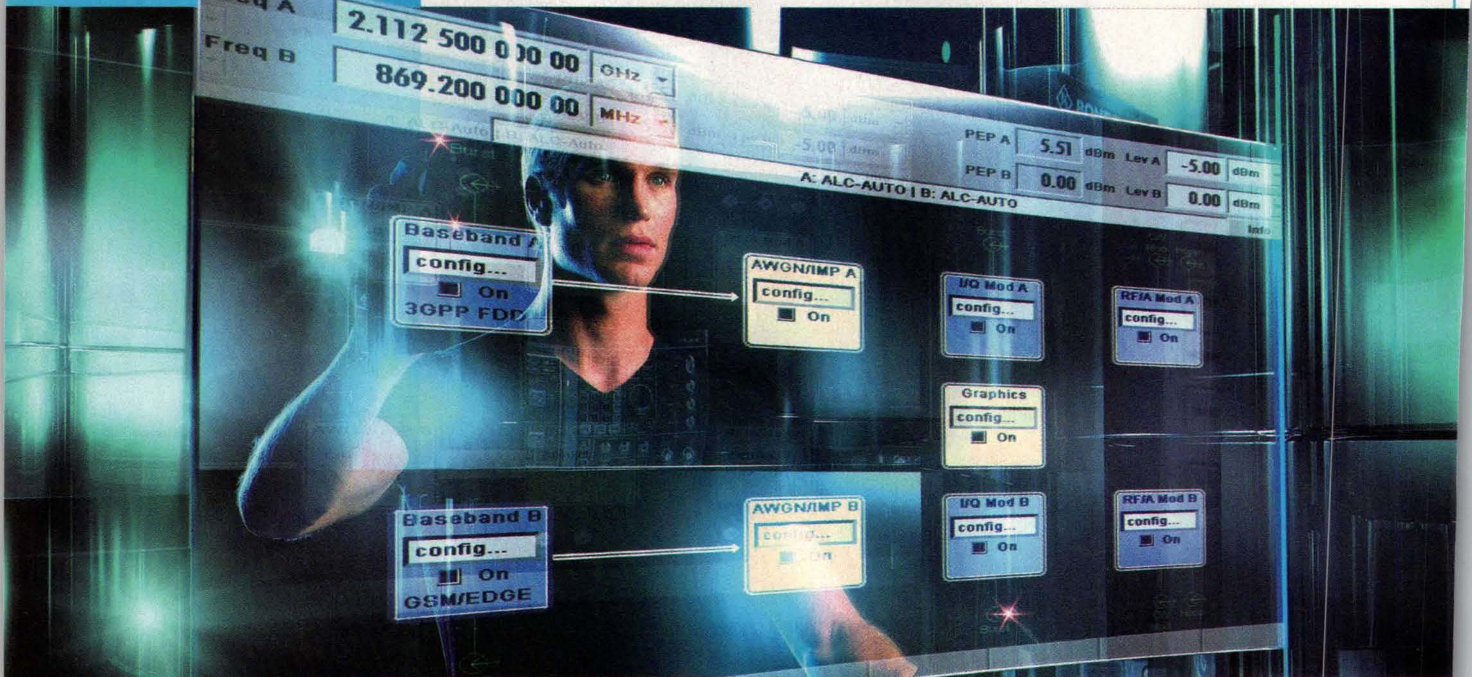

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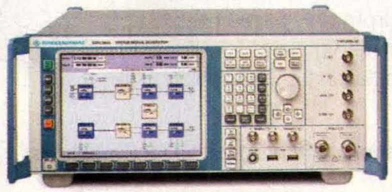

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DESIGN

Simple PBG Structures Serve Microwave Designs

Photonic bandgap structures offer the potential of low-cost fabrication and good bandstop characteristics for a variety of active and passive microwave circuits.

JWO-SHIUN SUN
GUAN-YU CHEN
Researchers
Department of Electronic Engineering, National Taipei University of Technology, Taipei, Taiwan, ROC; e-mail: jss@en.ntut.edu.tw.

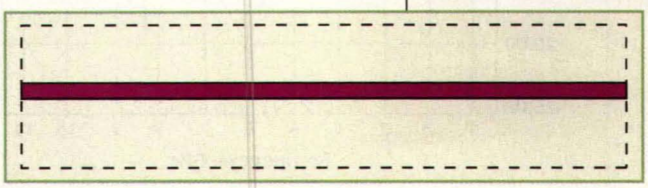
Photonic-bandgap (PBG) structures provide effective and flexible means of controlling electromagnetic (EM) waves along a specific direction. PBG structures are formed with microstrip lines and simple periodic perforations on a ground plane. By controlling the position of a microstrip line in relation to the perforations, PBG structures can be fabricated with stopband responses. They can be used for a variety of microwave applications, including antennas, power amplifiers (PAs), and filters, and can be effectively modeled by means of full-wave EM analysis and simulation.

Microstrip PBG structures are essentially sections of microstrip line with perforation patterns etched on the ground plane.[1-3] A variety of designs have been developed, and their bandstop and slow-wave characteristics studied.[4-6]

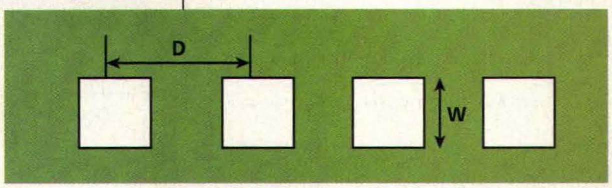
One area in which PBG structures may play a significant role is in the design of high-efficiency PAs. The efficiency of such amplifiers is typically improved by tuning harmonic frequencies, often by adding open- or short-circuit stubs at the output port. However, the use of PBG structures for harmonic tuning in a PA may not only increase power efficiency, but have the added benefit of suppressing undesired harmonic radiation.[7,8] PBG structures also offer the potential to achieve high efficiency over broader bandwidths than conventional harmonic tuning techniques.

Some researchers have reported a new tunable PBG resonator[9,10] that works in conjunction with a piezoelectric transducer (PET). The PET is used to perturb the EM fields incident on a PBG resonator, thus changing the effective length of the resonant line and shifting the resonant frequency of the structure.

Researchers have also studied a dielectric resonator filter with whispering gallery modes based on a PBG structure[11,12] as well as the effects of PBG structures on suppressing the harmonic resonances of an antenna.[13,14] In the



1. Electromagnetic modeling of PBG structures is based on the use of a quasi-TEM microstrip line.



2. The PBG structure under analysis is based on precisely placed holes in a high-frequency substrate.

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D3I0118	1.6-1.8	20	.40	1.25	3	$210.00
D3I0120	1.7-2.0	20	.40	1.25	3	$210.00
D3I0223	2.0-2.3	20	.40	1.25	3	$210.00
D3I2040	2.0-4.0	18	.50	1.30	1	$215.00
D3I2060	2.0-6.0	14	.80	1.50	1	$250.00
D3I2080	2.0-8.0	10	1.50	2.00	1	$395.00
D3I3060	3.0-6.0	19	.40	1.30	2	$195.00
D3I4080	4.0-8.0	20	.40	1.25	3	$185.00
D3I6012	6.0-12.4	17	.60	1.35	6	$195.00
DMI6018	6.0-18.0	14	1.00	1.50	11	$275.00
D3I7011	7.0-11.0	20	.40	1.25	4	$185.00
D3I7012	7.0-12.0	20	.40	1.25	4	$205.00
D3I7018	7.0-18.0	15	1.00	1.50	5	$225.00
D3I8012	8.0-12.4	20	.40	1.25	4	$180.00
D3I8016	8.0-16.0	17	.60	1.35	5	$205.00
D3I8020	8.0-20.0	15	1.00	1.45	5	$230.00
D3I1020	10.0-20.0	16	.70	1.40	5	$220.00
D3I1218	12.0-18.0	20	.50	1.25	5	$180.00
D3I1826	18.0-26.5	18	.80	1.40	5	$225.00
D3I1840	18.0-40.0	10	2.00	2.00	5*	$1300.00
D3I2004	20.0-40.0	12	1.50	1.65	5*	$950.00
D3I2640	26.5-40.0	14	1.00	1.50	5*	$700.00

Circulators

Model #	Freq Range GHz	Isol Min	Insertion Loss Max	VSWR Max	Outline #	Price Per Unit
D3C0890	.8-.9	20	.40	1.25	8	$235.00
D3C0116	1.4-1.6	20	.40	1.25	8	$235.00
D3C0118	1.6-1.8	20	.40	1.25	3	$210.00
D3C0120	1.7-2.0	20	.40	1.25	3	$210.00
D3C0223	2.0-2.3	20	.40	1.25	3	$210.00
D3C2040	2.0-4.0	18	.50	1.30	1	$215.00
D3C2060	2.0-6.0	14	.80	1.50	1	$250.00
D3C2080	2.0-8.0	10	1.50	2.00	1	$395.00
D3C3060	3.0-6.0	19	.40	1.30	2	$195.00
D3C4080	4.0-8.0	20	.40	1.25	3	$185.00
D3C6012	6.0-12.4	17	.60	1.35	6	$195.00
DMC6018	6.0-18.0	14	1.00	1.50	11	$275.00
D3C7011	7.0-11.0	20	.40	1.25	4	$185.00
D3C7018	7.0-18.0	15	1.00	1.50	5	$225.00
D3C8016	8.0-16.0	17	.60	1.35	5	$205.00
D3C8020	8.0-20.0	15	1.00	1.45	5	$230.00
D3C1218	12.0-18.0	20	.50	1.25	5	$180.00
D3C1826	18.0-26.5	18	.80	1.40	5	$225.00
D3C1840	18.0-40.0	10	2.00	2.00	5*	$1750.00
D3C2004	20.0-40.0	12	1.50	1.65	5*	$1350.00
D3C2640	26.5-40.0	14	1.00	1.50	5*	$900.00

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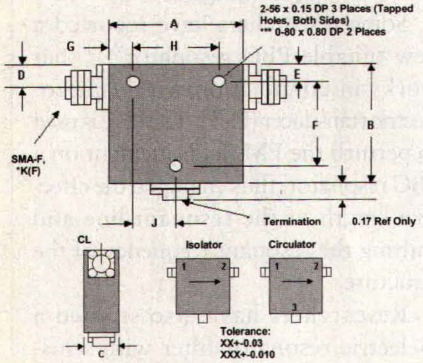


Inches

Outline #	A	B	C	D	E	F	G	H	J
1	1.58	1.62	0.70	0.25	0.25	1.265	0.10	1.380	0.690
2	1.25	1.25	0.70	0.25	0.25	0.900	0.10	1.050	0.525
3	1.00	1.00	0.50	0.25	0.25	0.675	0.10	0.800	0.400
4	0.86	0.98	0.50	0.25	0.25	0.625	0.10	0.660	0.330
5	0.50	0.70	0.50	0.25	0.18	0.455	0.08	0.340	0.170
6	0.62	0.78	0.50	0.25	0.25	0.425	0.10	0.420	0.210
8	1.25	1.25	0.72	0.26	0.26	0.900	0.10	1.050	0.525
11***	0.50	0.58	0.38	0.19	0.19	—	0.10	0.300	—

current study, the effects of a 50-Ω microstrip line placed at various positions above fixed periodic square holes on a microstrip ground plane were studied for the effects on the perturbation of EM waves, with the intent of finding optimal positions for the transmission lines.

In order to understand the importance of positioning the microstrip transmission lines in the design of PBG structures, it will be necessary to perform a few simple calculations for basic circuit-board parameters. For example, the effective dielectric constant, ϵ_e and characteristic impedance, Z_0, for a quasi-transverse-electromagnetic (TEM) microstrip line (**Fig. 1**) are approximated in refs. 15 and 16. The effective dielectric constant can be found from:

$$\varepsilon_\varepsilon = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\,\frac{1}{\sqrt{1 + {}^{12d}\!/_{W}}} \qquad (1)$$

while the characteristic impedance can be found from:

$$Z_0 = \frac{60}{\sqrt{\varepsilon_\varepsilon}}\, \ln\left(\frac{8d}{W} + \frac{W}{4d}\right) \text{ for } W / d \leq 1 \qquad (2$$

SEE EQUATION 3 AT RIGHT

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_\varepsilon}\left[{}^{W}\!/_{d} + 1.393 + 0.667\, \ln\left({}^{W}\!/_{d} + 1.444\right)\right]} \text{ for } W / d \geq 1 \qquad (3)$$

where:

D = the height of the dielectric substrate, and

W = the width of the microstrip line.

The center frequency of the stopband[12,13] for the PBG structure shown in **Fig. 2** is given by:

$$f = \frac{0.5 \times c}{D \times \sqrt{\varepsilon_\varepsilon}} \qquad (4)$$

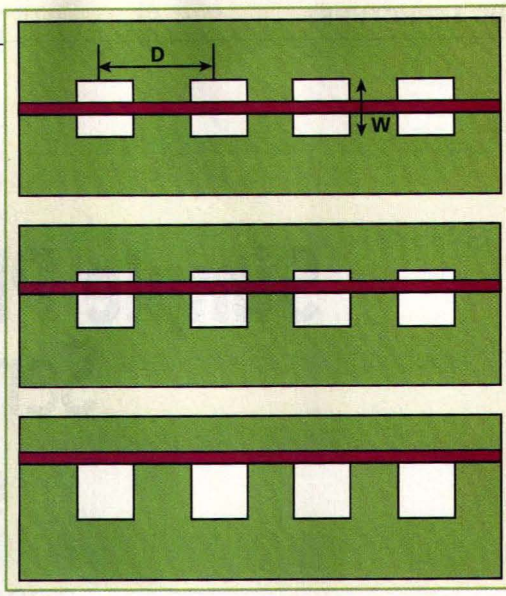
where:

f = the frequency of the stopband width with *a* number holes,

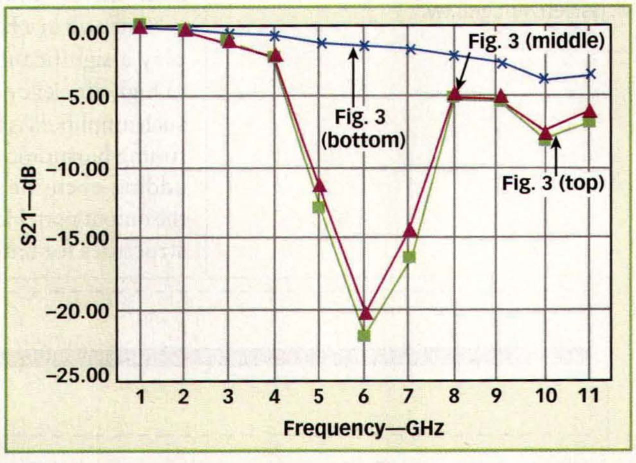
c = the speed of light, and

D = the distance between the periodic holes on the ground plane.

In order to understand the potential of PBG structures for microwave applications, a 50-Ω microstrip line was analyzed at various positions above fixed periodic square holes on a ground plane. Analysis was performed with the computer-aided-engineering (CAE) software suite Microwave Office 2000[17] from Applied Wave Research (El Segundo, CA) in order to study the EM behav-



3. The bandstop response of the PBG structure can be modified from a microstrip transmission line centered over the holes (top) to positions along the upper part of the holes (middle) and along the top part (bottom) of the holes in the dielectric substrate.



4. These simulated results show the S_{21} responses for the microstrip structures shown in Fig. 3.

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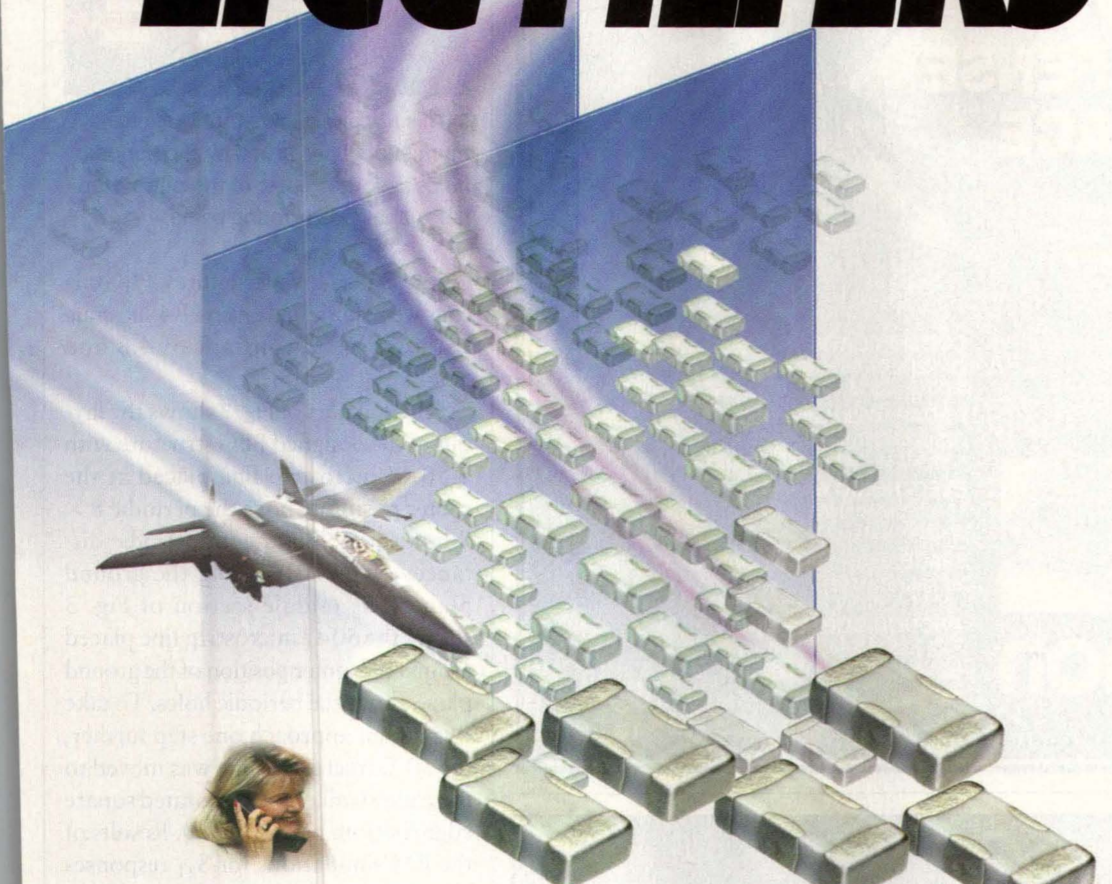

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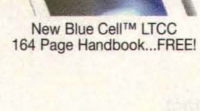

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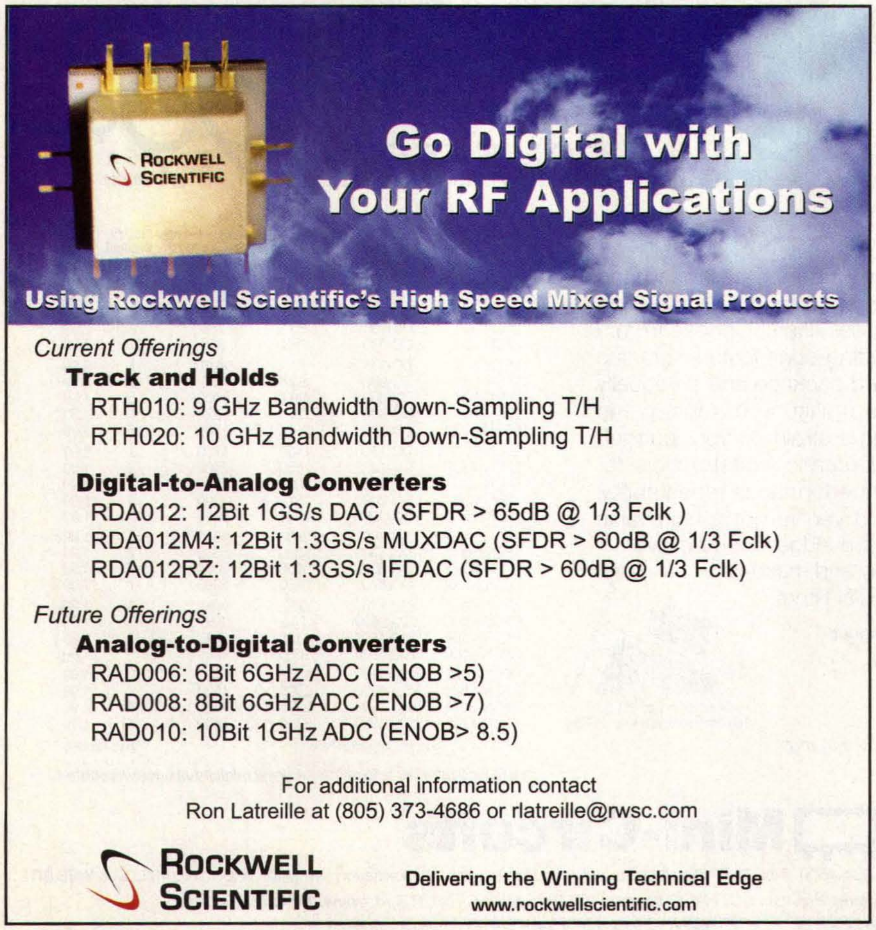

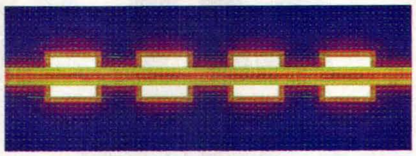

5. This EM plot shows that the maximum energy perturbed by the periodic holes is at the center of the perforated holes above the ground plane.

ior of various PBG structures. PBG circuits were fabricated on an FR4 substrate with dielectric constant of 4.8 and height of 1.48 mm.

The top part of **Fig. 3** shows the layout of the designed PBG structure with a 50-Ω microstrip line placed at the center position above the periodic 8 × 8-mm square holes with periodic distances of D = 2W along the ground plane. The middle section of Fig. 3 shows the 50-Ω microstrip line placed around the center position of the ground plane above the periodic holes. To take this design approach one step further, the 50-Ω microstrip line was moved to the fringe wall of the perforated square edge (bottom part of Fig. 3). Results of the EM simulations for S_{21} responses are shown in Fig. 3.

Obviously, the centered microstrip line incorporated with the PBG structure show clear bandstop character, which can be exploited to reject unwanted frequencies. **Figure 4** shows the EM-simulated data of S_{21} of Fig. 3 with a 50-Ω microstrip line standing aside the center position of periodic square holes in the ground plane. The PBG structure was found to exhibit similar performance compared to the middle section of Fig. 3. Figure 4 shows the simulated results of the bottom section of Fig. 3, with the 50-Ω microstrip line positioned along the fringe of the perforated square holes. The response can be approached as a lossy 50-Ω line without effective perturbation on the PBG structure. **Figure 5** demonstrates that the maximum energy perturbed by periodic holes is at the center of the perforated holes above ground plane.

Figure 6 shows measured responses for the results reported in Fig. 3. Measurements agree fairly closely with sim-

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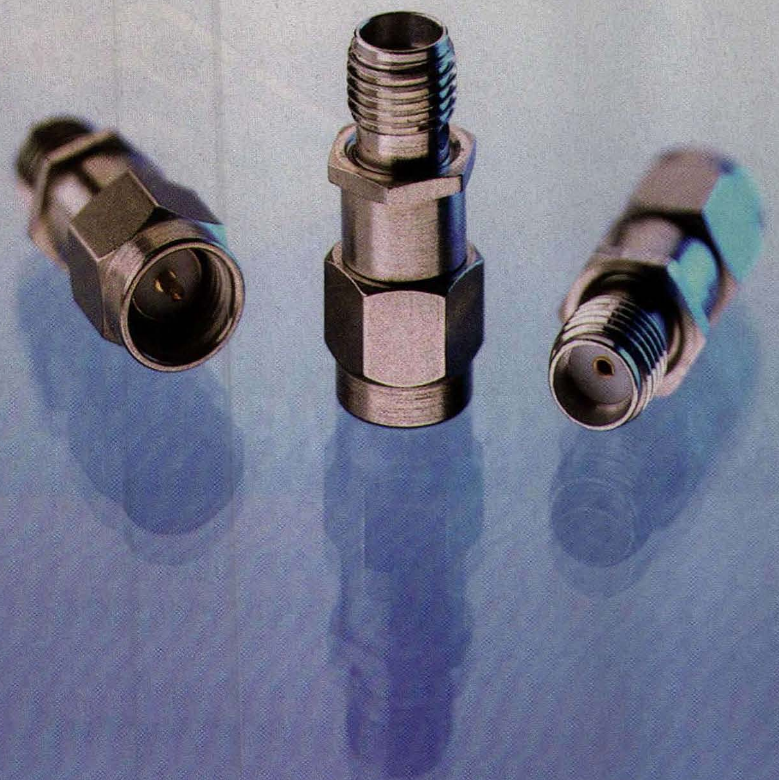

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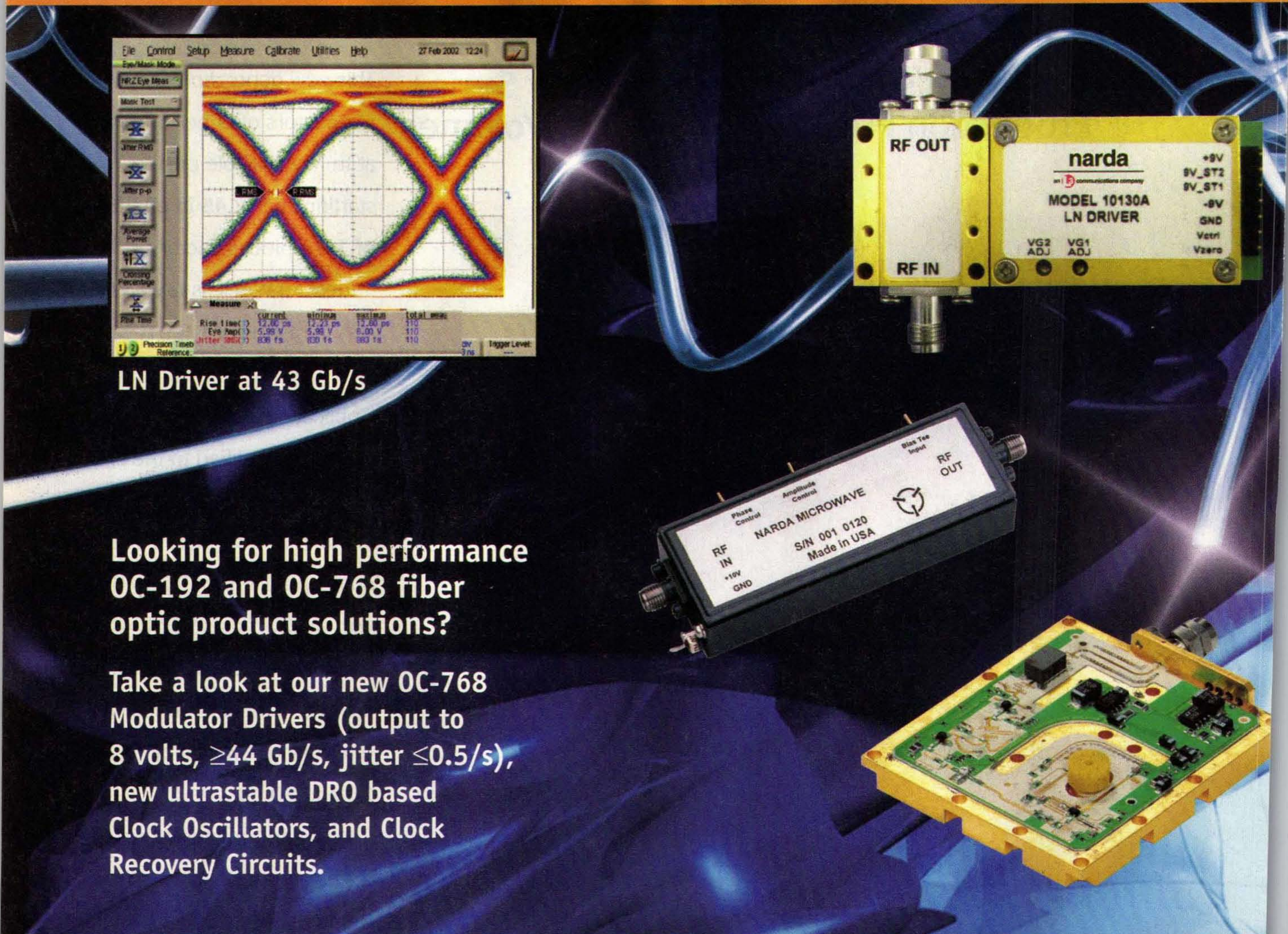

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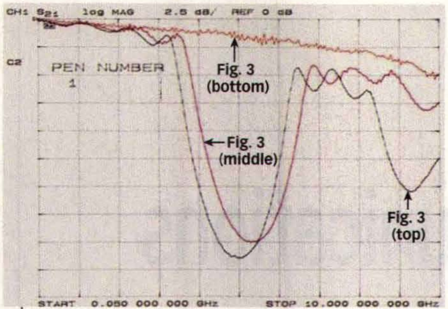

6. These are the measured responses for the simulations shown in Fig. 4.

ulated responses. Further measurements (not shown) indicate a stopband region for effective rejection of harmonic responses.

In summary, several simple PBG structures were realized using microstrip lines on perforated ground planes. These PBG structures exhibit usable bandstop-filter characteristics due to the positioning of the microstrip relative to the perforated ground plane. By cascading the perforated square cells, a practical PBG microstrip transmission line can be fabricated with strong bandstop character. Using EM CAE tools, it was possible to achieve fairly good agreement between PBG simulations and measured results. MRF

ACKNOWLEDGMENTS

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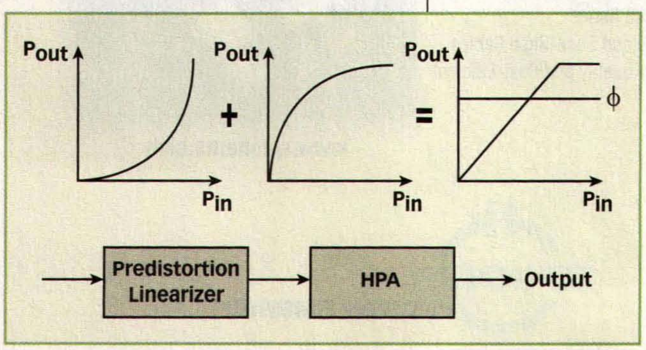
Microwave power modules (MPMs) have been widely used in military applications, including radar and electronic-warfare (EW) systems, but less so in communications applications because of their limited linearity. By combining an MPM with a linearizer, however, it is possible to use these robust microwave and millimeter-wave power amplifiers for communications applications requiring as much as 250 W output power.

An MPM combines a solid-state driver amplifier with a miniature traveling wave tube (TWT) and an electronic power converter in a single compact housing.[1,2] It blends the small size, high gain, and low noise of solid-state devices at low power levels with the high efficiency and small size of TWT technology at higher power levels. MPMs offer a ten-to-one improvement in power density (power per unit weight) and a four-to-one power conversion efficiency over comparable solid-state power amplifiers (SSPAs).[3] MPMs also offer a significantly lower noise figure than conventional TWTAs, and can provide all these advantages with superior reliability and at a lower cost than comparable power SSPAs.[4]

Unfortunately, MPMs are limited in linearity performance, a key parameter in modern communications systems.[5] Complex modulation schemes, often referred to as bandwidth-efficient modulation (BEM), are employed in these systems to maximum the amount of information that can be transmitted over relatively narrowband channels. BEM requires amplifiers with high linearity to reduce errors and minimize adjacent-channel leakage ratio (ACLR). Fortunately, by combining a solid-state linearizer with an MPM, comparable or superior linearity to an SSPA be achieved.[6]

MPMs operate from below 2 GHz to past 45 GHz.



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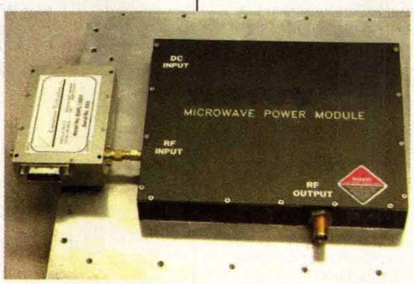

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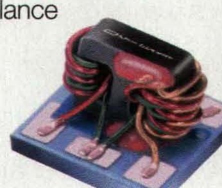

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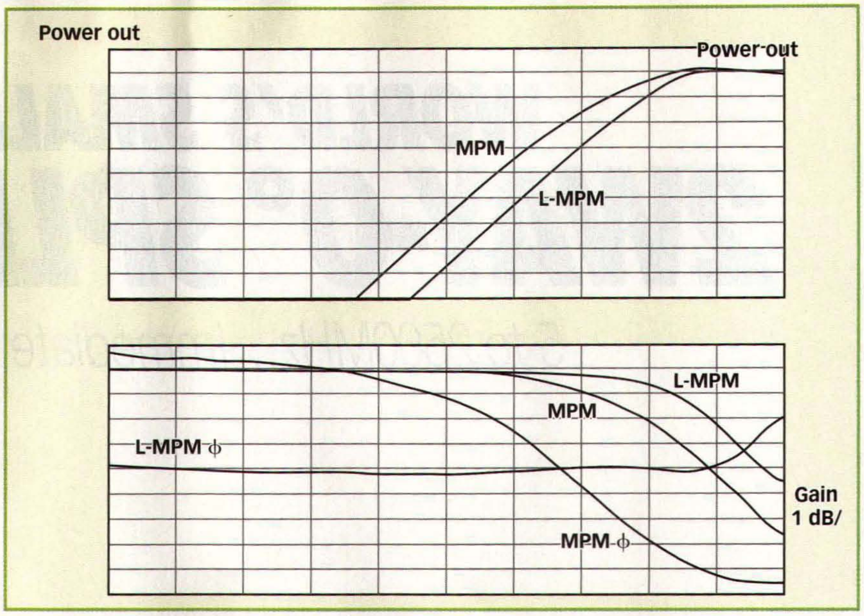
Standard wideband models cover bands of 2 to 6, 6 to 18, and 18 to 40 GHz with RF output power levels up to 250 W, noise figures of less than 10 dB, and efficiency to 50 percent.[7,8] MPMs are used for military applications, including unmanned aerial vehicles (UAVs), decoys, radars, and phased array systems. They are designed to be modular and can be reconfigured for different form factors and formats to meet changing systems needs. MPMs are available from a variety of suppliers, including CPI, L3 Communications, NEC, Northrop Grumman, and Triton.

Linearization improves the performance of an MPM by systematically reducing distortion.[9] Linearization approaches vary, but usually extra components are added to a conventional high-power amplifier (HPA). Often these extra components are configured as a subassembly or box that is referred to as a *linearizer*. Predistortion (PD) linearizers have been favored at microwave and higher frequencies because of their wideband performance, low power overhead, and ability to function as stand-alone units, and that approach is the basis for the study presented in this article. PD generates transfer characteristics exactly opposite in magnitude and phase to those of the power amplifier. The gain increase of the linearizer cancels the amplifier's gain decrease. Likewise, the phase change of



3. These plots show C-band MPM transfer responses with and without a linearizer.

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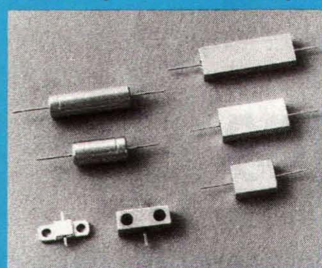

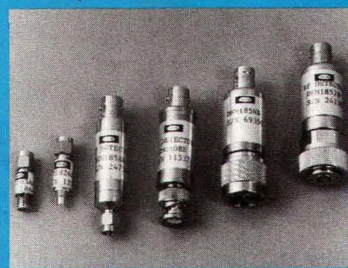

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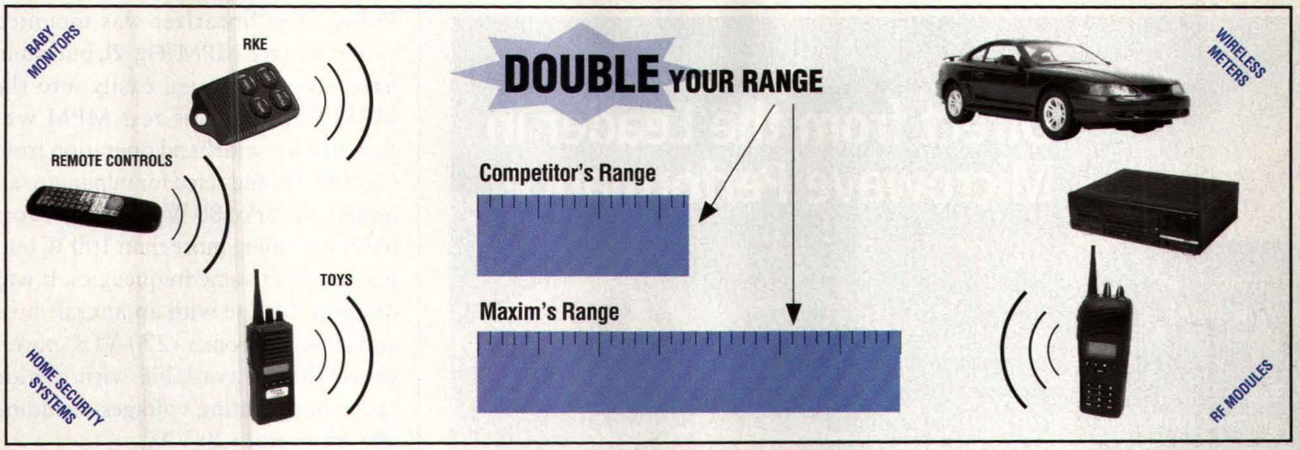

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the linearizer cancels the phase change of the amplifier. The desired result is an *ideal limiter* transfer characteristic **(Fig. 1)**. PD can provide large benefits, especially as output power is backed off from saturated levels. Alternately, PD can be viewed as a generator of intermodulation-distortion (IMD) products. If the linearizer-generated IMD is equal in amplitude and 180 deg. out phase with the IMD produced by the HPA, both groups of IMD signals will cancel. Linearizers are available for all frequency bands from UHF through Ka-band; in addition, several bands can be combined into a single unit.

Engineers at Linearizer Technology have tested linearizers with MPMs from both L3 Communications (formerly Litton Electron Devices, San Carlos, CA) and Triton although, for the purpose of this article, only the results for the L3 Communications MPMs are shown. The linearizer was mounted external to the MPM **(Fig. 2)**, but could have been integrated easily into the MPM housing. The test MPM was designed for wideband operation from 6 to 18 GHz and rated for minimum saturated power of 80 W, although capable of providing more than 100 W output power at some frequencies. It was designed for use with an aircraft buss and operated from a +270-VDC power source but is available with a wide range of operating voltages including +28 VDC and 120 VAC.

The performance of the linearized MPM (L-MPM) was tested at C-band (5.85 to 6.65 GHz), X-band (7.9 to 8.4 GHz), Ku-band (13.75 to 14.5 GHz, and DBS (17.3 to 18.4 GHz) uplink satellite bands. A single triband linearizer was used for the C-, X-, and Ku-band tests, with a separate K-band unit used for 18-GHz measurements.

The L-MPM was first power swept using a vector network analyzer and adjusted for *flat* gain and phase versus RF input drive. Testing was then conducted with different signal sources on each band. **Figure 3** shows the C-band transfer response of the L-MPM compared to the MPM by itself. The 1-dB compression point was moved from about 5 dB from saturation to within 2 dB. The phase change between small signal and saturation was reduced from more than 45 deg. to less than 1 deg.

Figure 4 shows the X-band transfer response. The 1-dB compression point was moved from about 6 dB from saturation to within 2.5 dB. The phase change between small signal and saturation was reduced from more than 45 deg. to less than 2.5 deg. At Ku-band, the 1-dB compression point was also moved from more than 6 dB from saturation to within 2.5 dB. The phase

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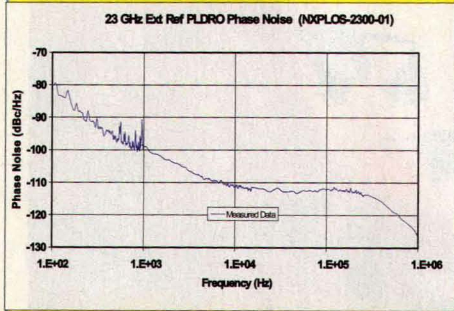

Phase Noise at 23 GHz (Typical)

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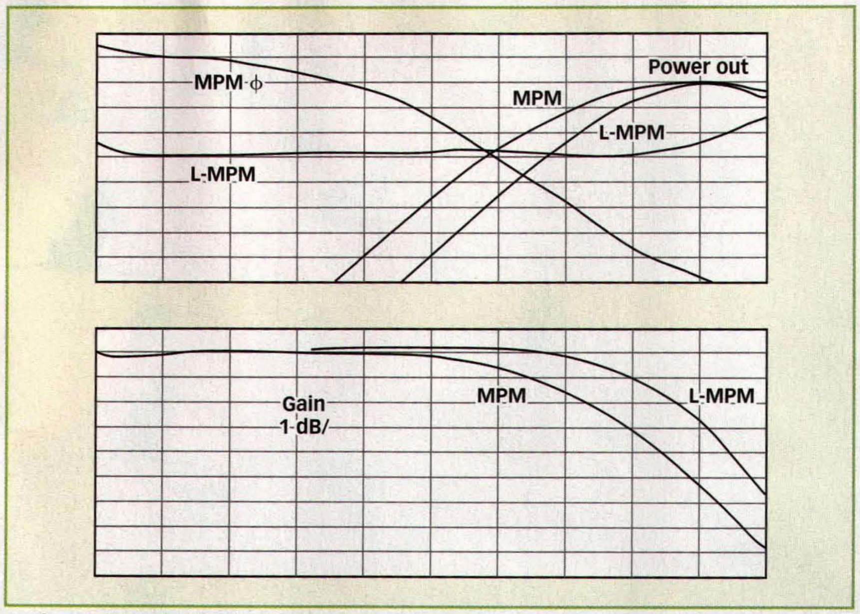


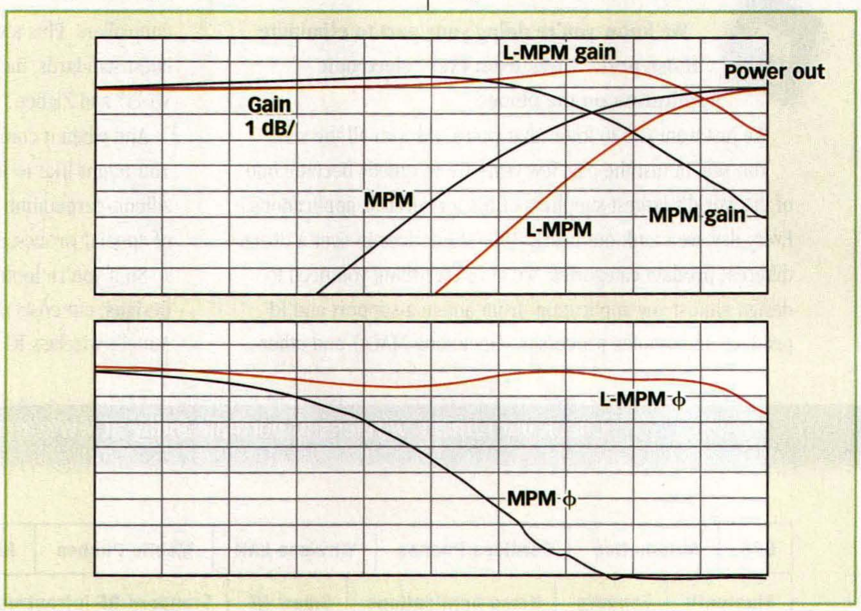
4. These plots show X-band MPM transfer responses with and without a linearizer.

change between small signal and saturation was reduced from more than 52 deg. to less than 8 deg.

At 18 GHz, the MPM displayed some gain overshoot, but was still easily linearized **(Fig. 5)**. With the addition of the linearizer, the 1-dB compression point moved from about 4 dB from saturation to within 0.5 dB, and the phase change was reduced from more than 60 deg. to less than 5 deg.

Figure 6 shows the measured two-tone carrier-to-intermodulation (C/I) ratios corresponding to these linearized and nonlinerized responses. Linearization provides more than a 15-dB increase in C/I for output-powerback off (OPBO) of greater than 4 dB at C-, X-, and Ku-band and more than 10 dB at DBS frequencies. For all bands, a more than 6-dB increase in effective power is provided by the linearizer for the minimum C/I of 26 dB required by most satellite operators, and a more than 6-dB increase in effective power was achieved for C/I ratios greater than 30 dB.

Next, the reduction in spectral regrowth (SR) or ACLR resulting from



5. These plots show the transfer characteristics of an MPM with and without a linearizer at DBS satellite-uplink frequencies.

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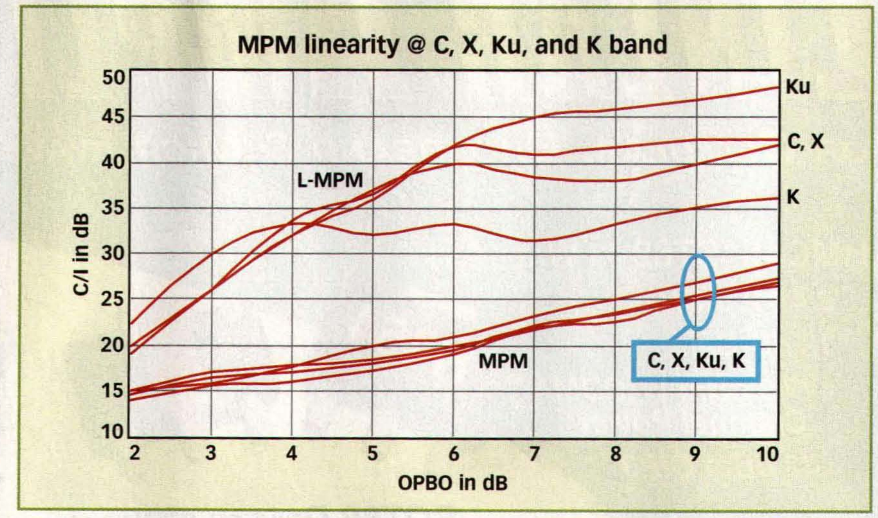
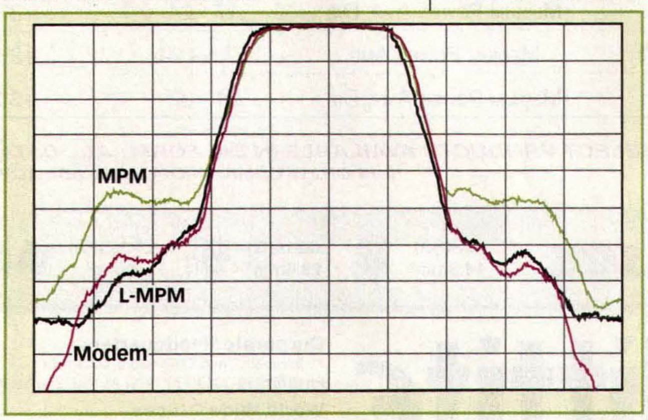


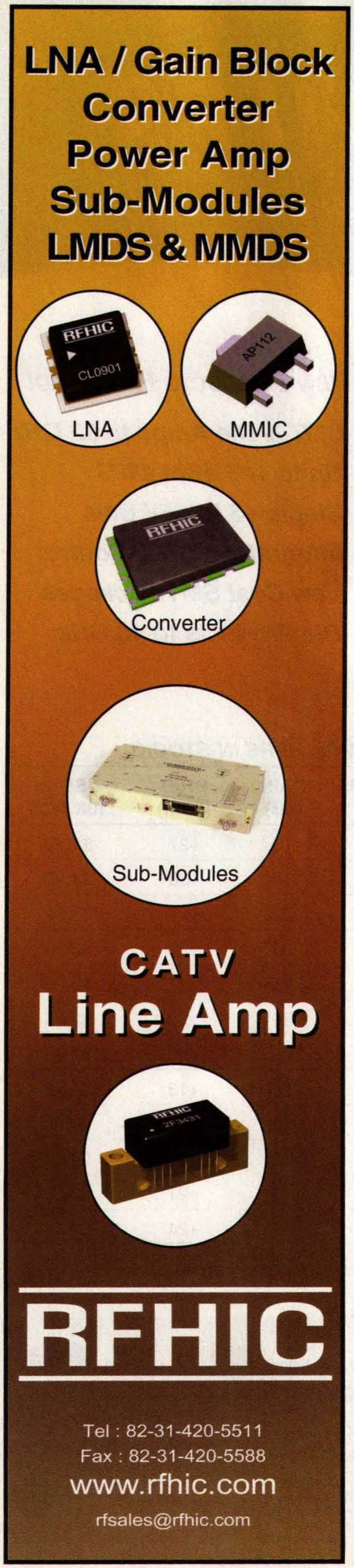
6. Linearization provides at least 6 dB more power for C/I ratios of more than 30 dB.

linearization was investigated. SR measurements were made at X-band, and later confirmed at C- and Ku-bands. At 0.5-dB OPBO, the linearizer provides a SR of better than 26 dB. At 2 dB OPBO, the linearizer can provide a SR of 30 dB. **Figure 7** shows not only the SR of the MPM and linearized MPM, but also the spectral response of the modem/upconverter. In addition, Figure 7 reveals that at some frequency points, the linearizer actually improves the input signal's spectrum. **Figure 8** shows a plot of SR versus OPBO with and without the linearizer. The observed improvement in SR was very close to results obtained with conventional TWTAs.[6] Similar results would be expected for OQPSK. It is expected that BPSK would provide about 1 dB poorer SR performance while 8PSK would provide about 1-dB improvement with the linearizer.[5]

The performance of the L-MPM with multiple carriers and with wide-band-code-division-multiple access (WCDMA) signals was measured. The performance of HPAs with multiple carriers (more than 10) is normally tested using a noise-power-ratio (NPR) measurement.[10] In this test, white noise is used to simulate the presence of many carriers of random amplitude and phase. The white noise is passed through a bandpass filter (BPF) to produce an approximately square spectral pedestal of noise about the same bandwidth as a signal of interest. This signal is then passed through a narrowband band-reject filter to produce a deep notch at the center of the noise pedestal. The depth of the notch at the output of the test HPA is the measure of the NPR. NPR can be considered a measure of multi-carrier intermodulation ratio (C/I). To evaluate the multicarrier performance of the MPM, a 40-MHz X-band noise pedestal was employed, a bandwidth typical of most satellite transponders. The results of this measurement are shown in **Fig. 9**. For an NPR of 16 dB, the linearizer achieves almost a 3-dB increase in effective output power,



7. These plots show the spectral-regrowth (SR) characteristics for MPMs with and without linearization at a 2-dB OPBO.



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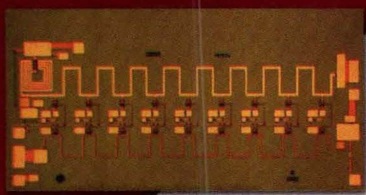

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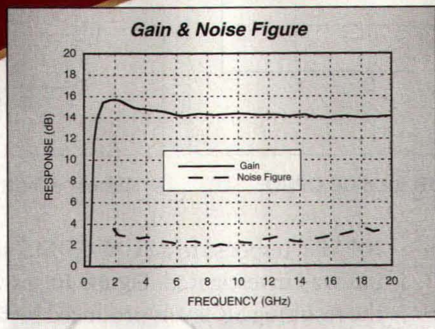

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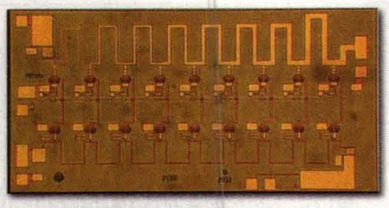
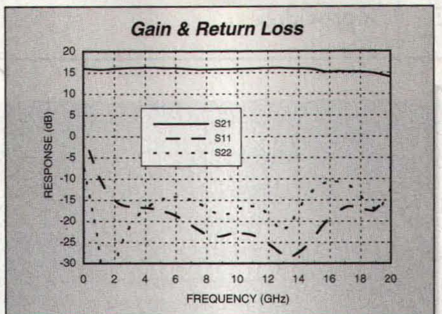


50 Ohm I/O Power Amp



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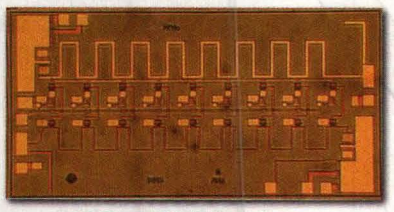
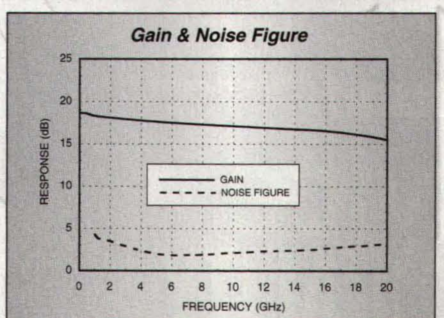


50 Ohm I/O Driver Amp



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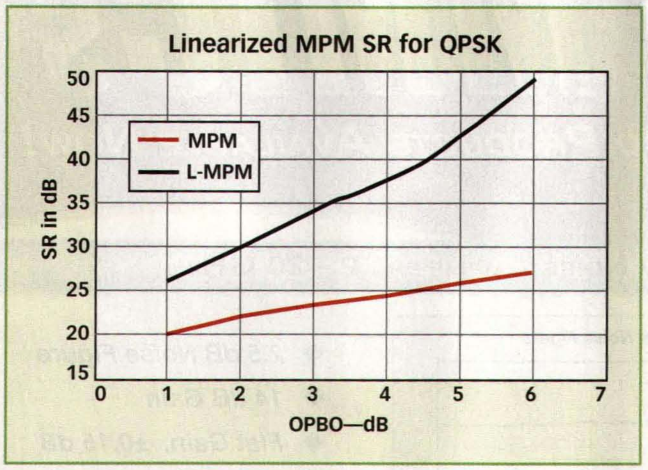
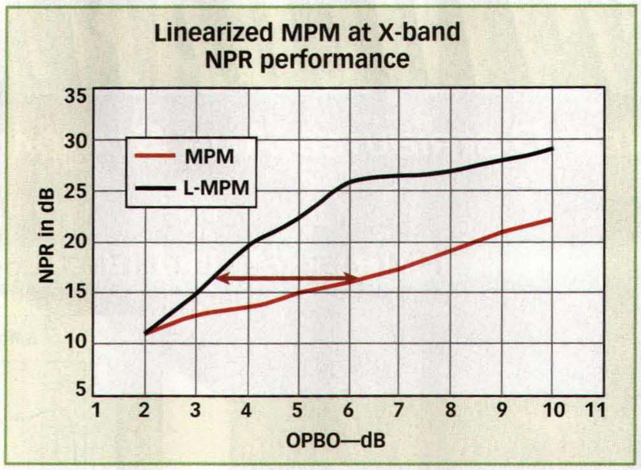


8. The SR is reduced by more than 20 dB for 6-dB OPBO.



9. Almost a 3-dB increase in power is provided for a 16-dB NPR.

and for an NPR of 20 dB more that a 4.5-dB power advantage.

In addition to its use in cellular telephones, CDMA technology is also finding its way into satellite-based and the communications systems. SR (ACLR) is a major concern in these applications.[11] The SR produced by an L-MPM in response to a 3G WCDMA signal was investigated. **Figure 10** shows the resulting SR levels produced by the MPM and the L-MPM at 2.5- and 5-MHz offsets. For a 2.5-MHz WCDMA channel bandwidth and an SR of 30 dB, more than 6 dB of additional power is provided.

Amplifier power consumption is a major concern in many communications applications. It can be a major cost driver and in some instances determine a project's feasibility. The efficiency of the test MPM was not optimum and varied with frequency because of its wideband design. In X-band the overall effi-

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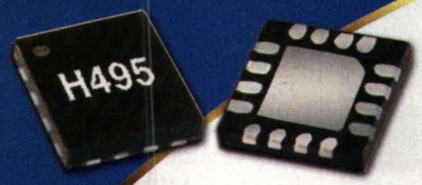

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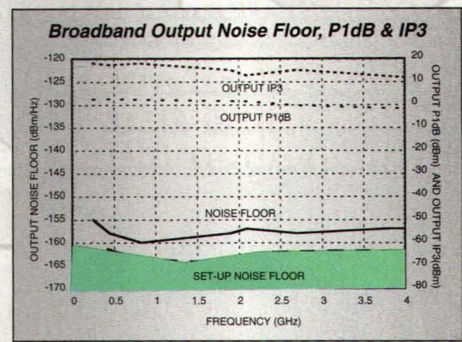

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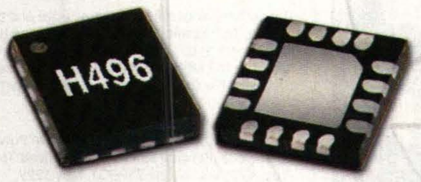

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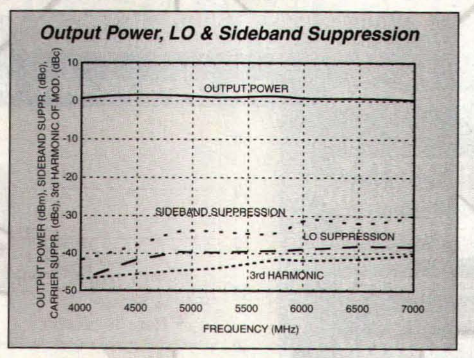

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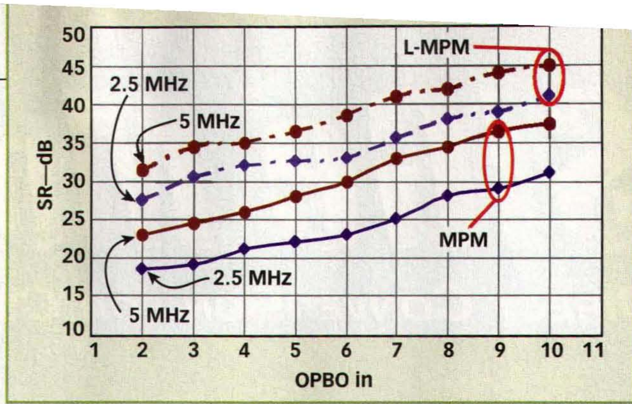
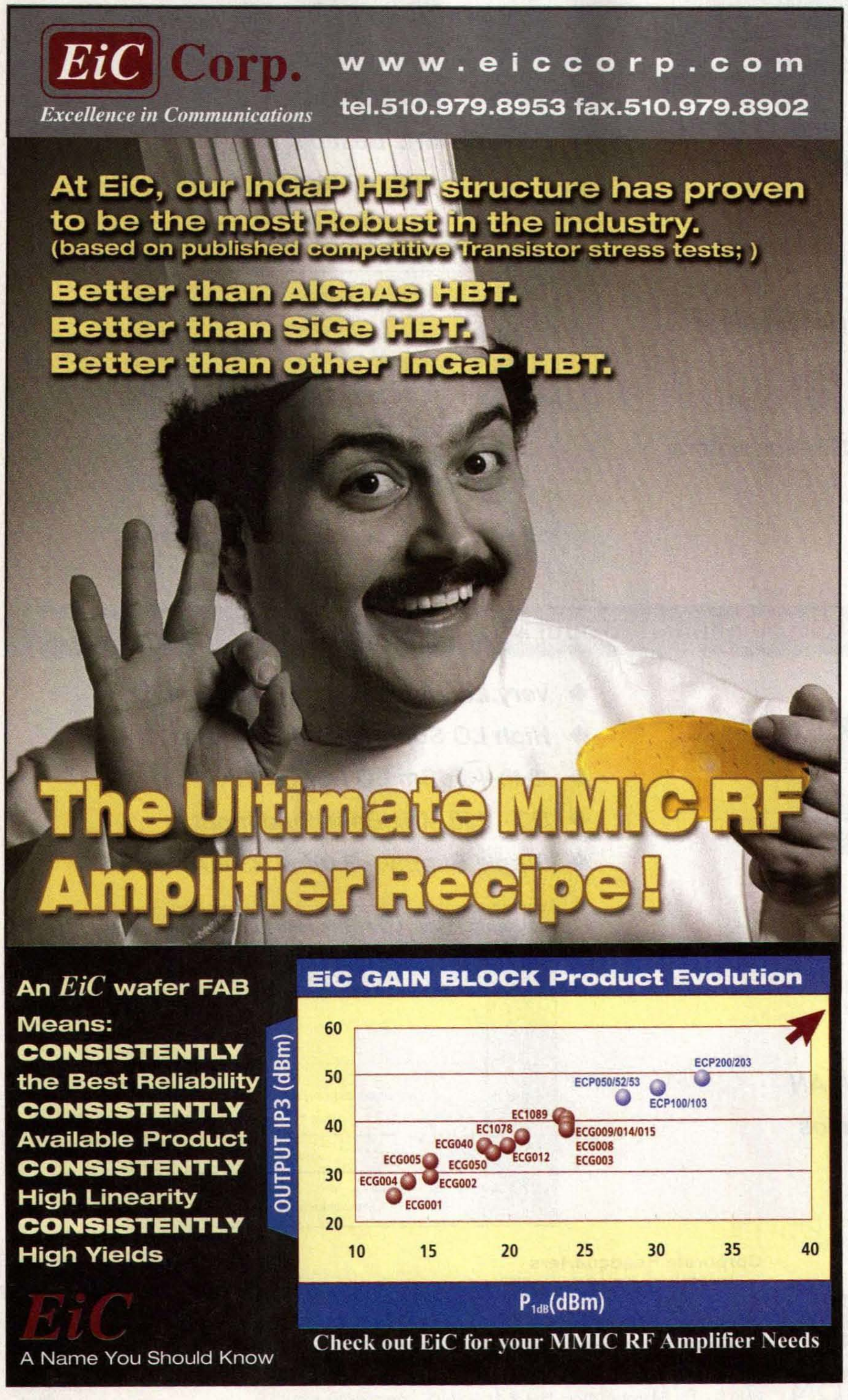
ciency (TWT, driver amplifier, power supply) of the MPM at saturation was measured as more than 35 percent, but varied with frequency. For a two-tone C/I of 26 dB, linearization provides more than 3-to-1 improvement in efficiency! Linearization boosts efficiency from less than 7 percent to more than 22 percent in the high-efficiency case.

These results clearly show the enormous value of combining an MPM with a linearizer. This combination makes linearized MPMs attractive for commercial and military communications applications. A linearized MPM provides significantly higher power, efficiency, and linearity than other options. A linearizer helps an MPM achieve four times the output power for C/Is greater than 30 dB, and more than a 10-dB improvement in C/I over much of its power range. A linearizer allows QPSK operation with an SR of more than 30 dB at 50 W output power with overall efficiency of 25 percent, with similar advantages for WCDMA. All this is provided in a box that can be less than 50 in. (127 cm)^3 in volume, 5 lbs. (2.25 kg) in weight, and operate over multi-octave bandwidths. MRF



10. For a WCDMA signal with 2.5-MHz channel bandwidth, more than 6 dB of additional power is provided.



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Vector network analyzers are traditionally used to measure the continuous-wave (CW) S-parameter performance of components. Often, under these operating conditions, the analyzer is functioning as a narrowband measurement instrument. It transmits a known CW frequency to the component and measures the CW frequency response. If we were to look at the response of a single CW frequency, we would see a single spectral tone in the frequency domain. The analyzer has a built-in source and receivers that are designed to operate together in a synchronous manner, utilizing narrowband detection, to measure the frequency response of the component. Most analyzers can be configured to generate a frequency sweep over many frequency tones.

In some cases, the signal applied to the component must be pulsed (turned on and off) at a specific rate and duration. If we were to look at the frequency-domain response of a single pulsed tone, it would contain an infinite number of spectral tones making it challenging to utilize a standard narrowband VNA. This article describes how to configure and make accurate pulsed S-parameter measurements using a PNA vector network analyzer from Agilent Technologies (Santa Rosa, CA).

To see what the frequency-domain spectrum of a pulsed signal looks like, we first mathematically analyze the time-domain response. Equation 1 illustrates the time-domain relationship of a pulsed signal. This is generated by first creating a rectangular windowed version [rect(t)] of the signal with pulse width PW. A shah function is then realized consisting of a periodic train of impulses spaced 1/PRF apart where PRF is the pulse-repetition frequency. This can also be viewed as impulses at spacing equal to the pulse period. The windowed version of the signal is then convolved with the shah function to generate a periodic pulse train in time corresponding to the pulsed signal:

$$y(t) = \left[rect_{PW}(t)x(t)\right] * shah_{1/PRF} \qquad (1)$$

To look at this signal in the frequency domain, a Fourier transform is performed on the pulsed signal y(t):

$$Y(s) = \left[PW \times \sin c(PW \times s) * X(s)\right]\left[PRF \times shah(PRF \times s)\right]$$
$$Y(s) = \left[PW \times \sin c(PW \times s)\right]\left[PRF \times shah(PRF \times s)\right]$$
$$Y(s) = Duty\ Cycle \times \sin c(PW \times s) \times shah(PRF \times s) \qquad (2)$$

Equation 2 shows that the frequency-domain spectrum of the pulsed signal is a sampled sinc function with sample points (signal present) equal to the pulse-repetition frequency (PRF).

The left-hand side of **Fig. 1** shows what

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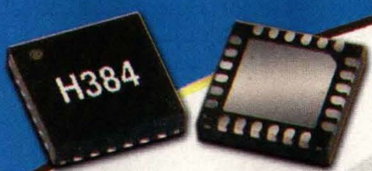

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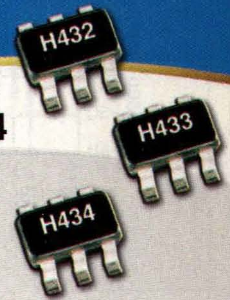

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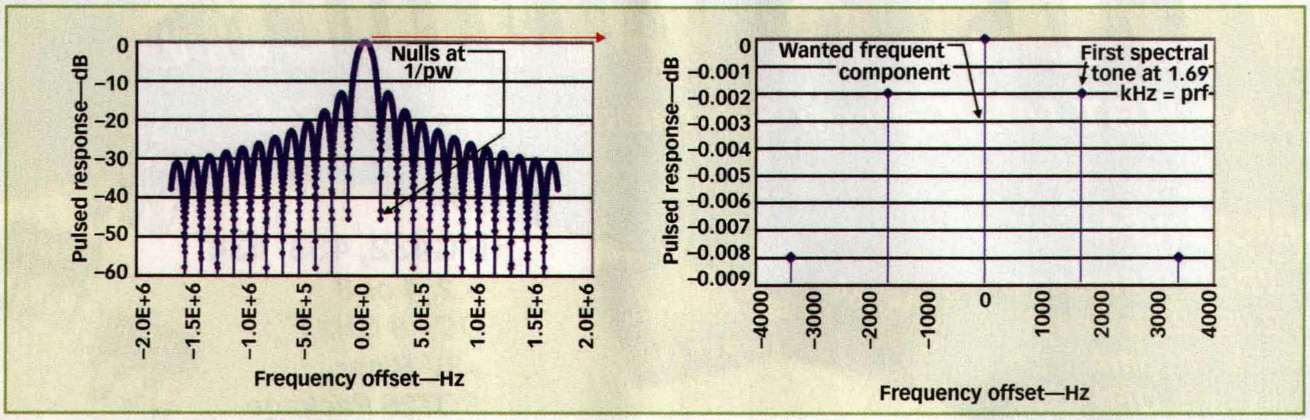
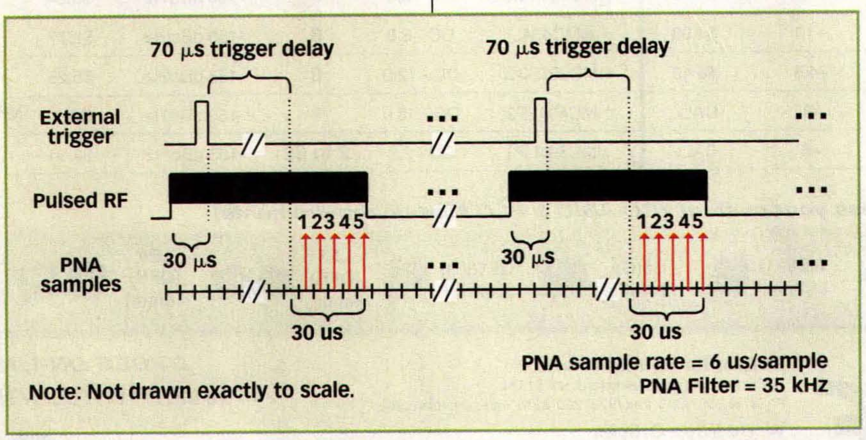


1. This frequency-domain display of a pulsed signal (left) can be shown in a zoomed-in view (right) to examine signal components.

the pulsed spectrum would look like for a signal that has a PRF of 1.69 kHz and a pulse width of 7 µs. The right-hand side of Fig. 1 shows the same pulsed spectrum with a zoomed-in view of the pulsed fundamental frequency. The spectrum has components that are nPRF away from the fundamental, where n is the harmonic number. The fundamental tone contains the measurement information. The PRF tones are artifacts of pulsing the fundamental tone, with relatively large magnitudes for those spectral components close to the fundamental tone.

The PNA vector network analyzer operates by means of narrowband detection of microwave energy. It down-converts a received signal to an intermediate frequency (IF) that is then digitized (sampled at discrete intervals) and digitally filtered for display and analysis. There are two different methods for measuring the S-parameters of a pulsed signal with a microwave PNA: "synchronic pulse acquisition" and "spectral nulling." Synchronic pulse acquisition is analogous to the "full pulse characterization" mode of operation on an 8510 vector network analyzer. Spectral nulling is analogous to the "High PRF" mode of operation in the 8510 series except that point-in-pulse and pulse-profiling can be performed whereas they could not on the 8510 in "High PRF" mode.

The synchronic-pulse-acquisition method provides synchronic timing between the individual incoming pulses and the analyzers discrete sampling. If the pulse width exceeds the minimum time to synchronize and acquire one or more discrete data points then the measurement falls into the synchronic pulse-acquisition mode of operation **(Fig. 2)** and the receiver performs at its full CW sensitivity and dynamic range with no pulse desensitization.



2. This is a time-domain representation of the vector analyzer's synchronic pulse-acquisition mode.

Pulse-to-pulse characterization can be measured in this mode with each displayed data point corresponding to one individual pulse. This measurement is configured by aligning the incoming pulses with the sampling intervals of the analyzer using trigger-on-point mode and applying an external trigger to measure each pulse. The analyzer must see 100 µs of pulsed signal before the acquisition period (less than the recommended 100 µs will result in reduced measurement performance). This accounts for PNA hardware filter settling. There is a 70-µs delay between the applied trigger and when the analyzer begins digitization of one discrete point. Therefore, a 30-µs delay should be applied between the incoming pulse and applied trigger to account for the 100 µs of pre-acquisition pulsed RF. The minimum acquisition time on the analyzer is roughly proportional to inverse of the intermediate-frequency (1/IF) bandwidth. As the IF bandwidth is decreased, the measurement acquisition time for each data point increases. The minimum acquisition time on the analyzer is 30 µs for an IF bandwidth setting of 35 kHz. This corresponds to a minimum measurable pulse width of 130 µs.

The synchronic mode of operation requires a pulse generator to supply the timing width and delays for the external triggering and the modulation. Modulation can be supplied by modulating the device-under-test (DUT) bias **(Fig. 3)** or modulating the source signal. A standard microwave PNA has both a trigger-in and trigger-out (ready for

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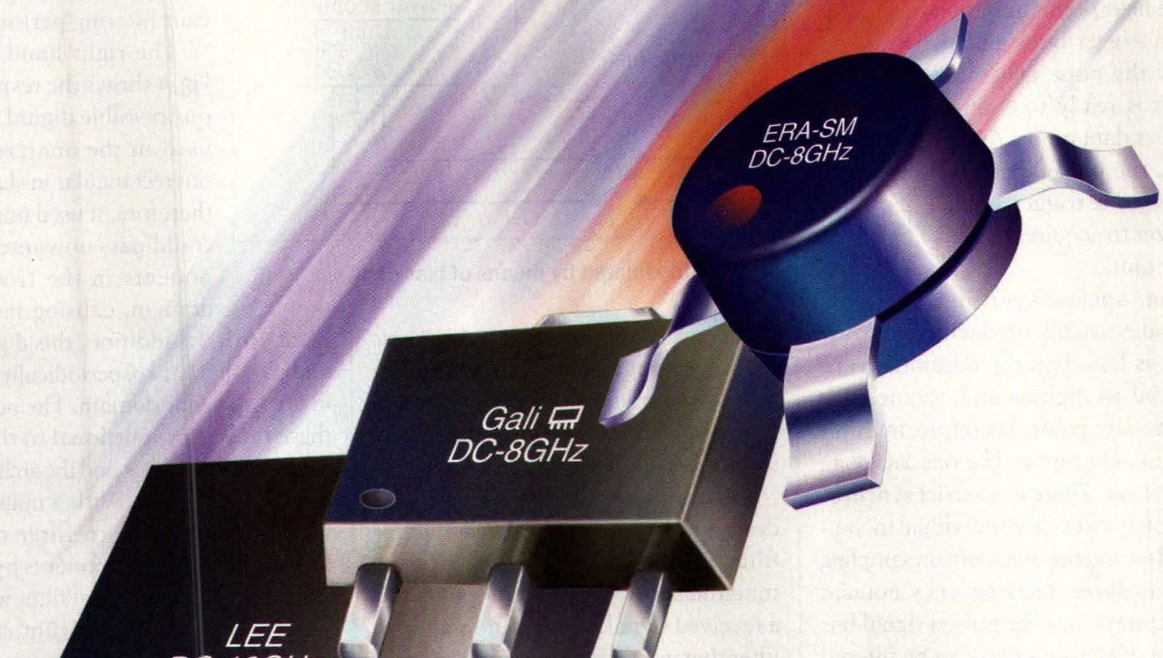

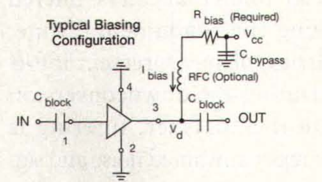

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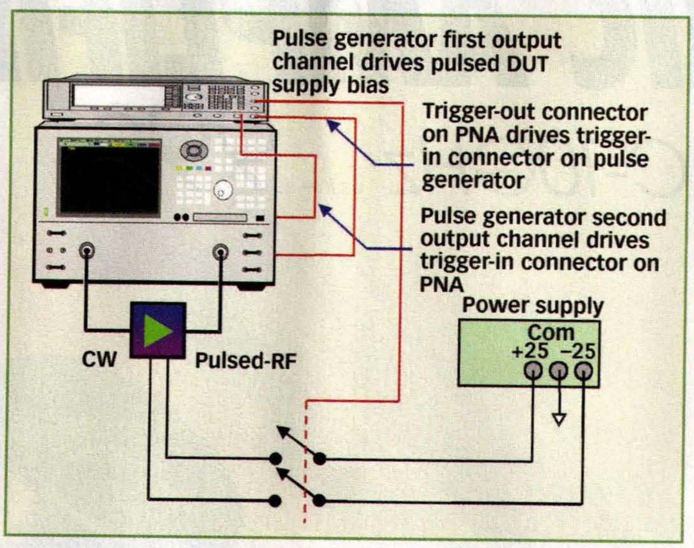
trigger) BNC connector that may be used to synchronize the trigger timing of the analyzer and pulse generator. In point mode, applying a trigger-in signal will cause the analyzer to acquire data for the first frequency point, move the source frequency to the next point, and then send a trigger-out signal to notify the pulse generator that it is ready to acquire the next data point. At this point, the pulse generator may send a trigger to the analyzer to acquire the next data point.

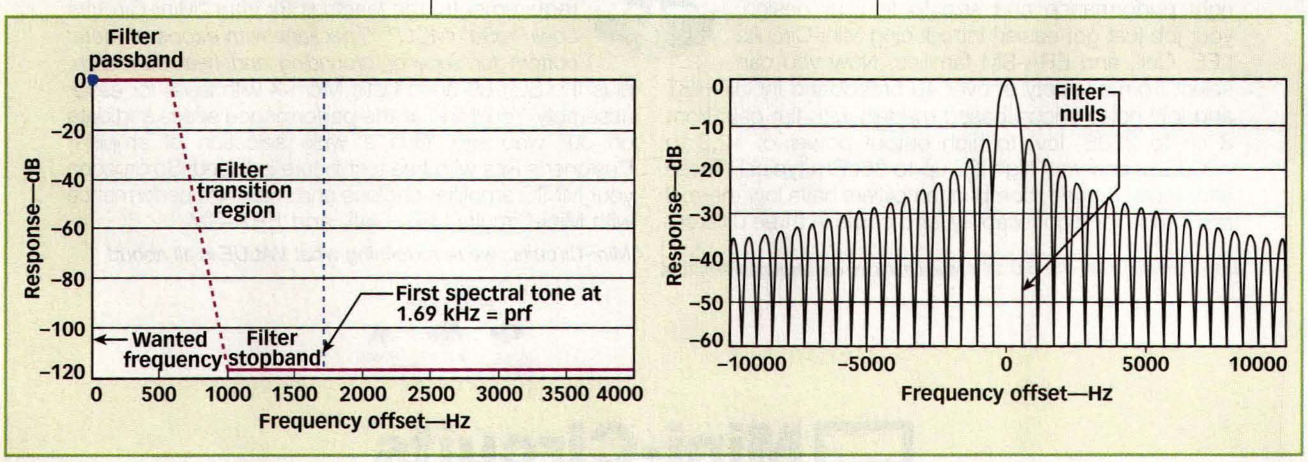


3. A DUT can be pulse modulated by means of bias control.

The spectral-nulling method is usually used when the pulse width is less than the minimum time required to digitize and acquire one discrete data point. Therefore, multiple pulses must be captured for one data point acquisition. There is no strict synchronization between the individual incoming pulses and the time-domain sampling of the analyzer. The frequency-domain representation of the pulsed signal has discrete PRF tones that can be filtered out, leaving the fundamental tone, which carries the measurement information. During the downconversion process in the analyzer, filtering is applied to reject unwanted noise and signal components. Once the signal is digitized, the analyzer applies a digital filter with an IF bandwidth specified by the user. Typically, this filter is used to reduce measurement noise and increase dynamic range. The digital filtering algorithm works well for non-pulsed signals, but what occurs when the receiver receives a pulsed signal?

With narrowband detection, it is desirable to use a digital rectangular filter to attenuate all but the pulsed fundamental-frequency component of a received signal. This would require a filter that would have a minimum stopband frequency less than the PRF of the pulsed signal with optimum rejection. The filter-transition slope should be well away from the first PRF tone **(Fig. 4, left)**, so that there is maximum rejection of the unwanted tones. This filter may be difficult to design because the PRF tones may be in close proximity to the fundamental tone. Strict rectangular filters in the frequency domain have some tradeoffs such as excessive ringing in the time domain. As such, filter designers adopt differing techniques to get the best performance in both frequency and time domain while still offering significant filtering performance.

The right-hand side of **Fig. 4** shows the response of one possible digital IF filter used in the analyzer. It is not rectangular in shape and therefore, if used unaltered, could pass unwanted components in the frequency domain, causing measurement error. In addition, this digital filter has nulls that are periodically spaced in the frequency domain. The period of these nulls is proportional to the sample rate of the receiver and the architecture of the digital filter. With a microwave PNA, it is possible to filter out the unwanted signal components by aligning the nulls of the digital filter with the unwanted pulsed spectrum components, leaving the fundamental tone **(Fig. 5)**. One advantage of this filtering technique is that the nulls of the filter are very deep and provide substantial rejection of the pulsed spectral components. Another advantage is that the nulls can be placed in close proximity to the fundamental tone because the transition regions at the nulls are very abrupt.



4. These frequency-domain displays show an "ideal" digital filter (left) and one of the PNA's digital filters (right).

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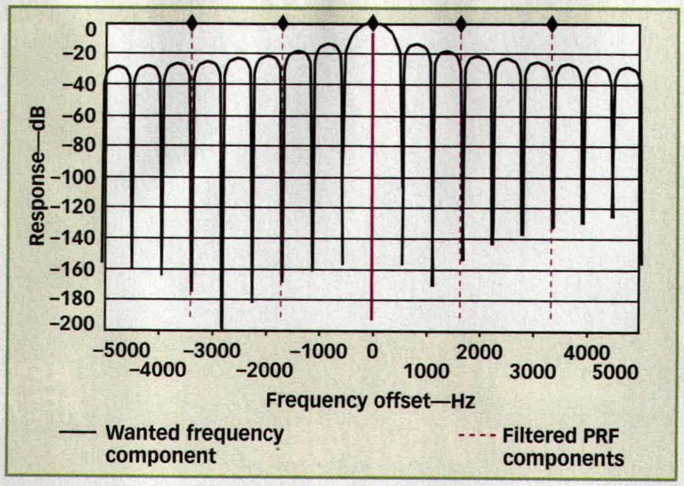
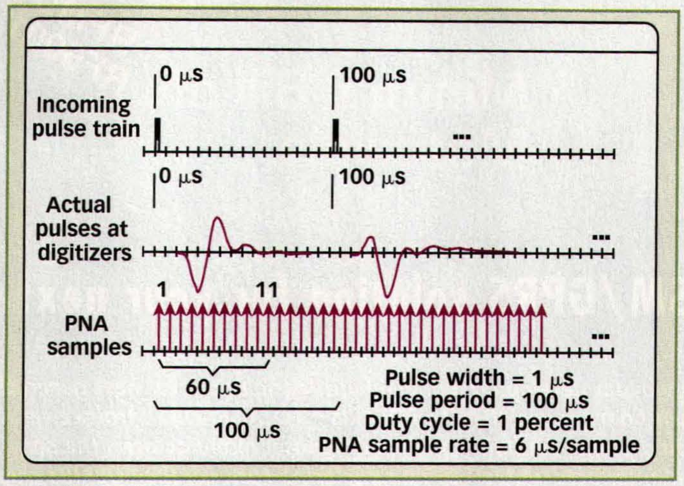
Figure 6 provides a representative view of the pulsed-signal and the analyzer-discrete samples for a time-domain view. The pulse that is digitized by the samplers has lost its original time-domain shape due to downconversion and various hardware filtering components applied to the pulse while traveling through the narrowband receiver. Accurate pulsed measurement information remains intact during this downconversion process. The pulse-to-pulse shape seen at the digitizers has changed due to the difference in the phase relationship between the PRF and the swept frequency. The number of pulses sampled during one data point acquisition is dependent on the IF bandwidth setting, pulse period and pulse width. In this example, a pulsed signal with a pulse period of 100 µs and a pulse width of 1 µs is being measured. The 500-Hz IF filter chosen for this measurement requires 292 samples, each spaced 6 µs apart, to display one data point on the analyzer display. During the acquisition time for one data point, the analyzer has been sent 17 pulses with each digitized sample containing data from a different part of the incoming pulses.

When using the spectral-nulling mode of operation, there is a loss in dynamic range corresponding to the duty cycle, equal to 20log(duty cycle). This is due to the narrowband filter rejecting everything except the fundamental tone of the pulsed signal. As the duty cycle decreases, more energy moves into the sidebands and less energy remains in the fundamental tone. This can be illustrated by analyzing Eq. 2 and noticing that the magnitude of the tones in the frequency domain decrease proportionally to the pulse width and the pulse-repetition frequency (i.e., duty cycle = pulse width × PRF). For some analyzers, this may limit measurement usability. One key benefit of using the microwave PNA in this configuration is that very narrow pulse widths (i.e., much less than 1 µs) can be used as long as the duty cycle is large enough to provide acceptable measurement dynamic range. As the duty cycle decreases, the dynamic range reaches a point where the measurement results may not have sufficient accuracy. The microwave PNA excels using narrowband detection because of its outstanding performance in trace noise and dynamic range over other network analyzers **(Fig. 7)** as well as the utilization of spectral nulling.

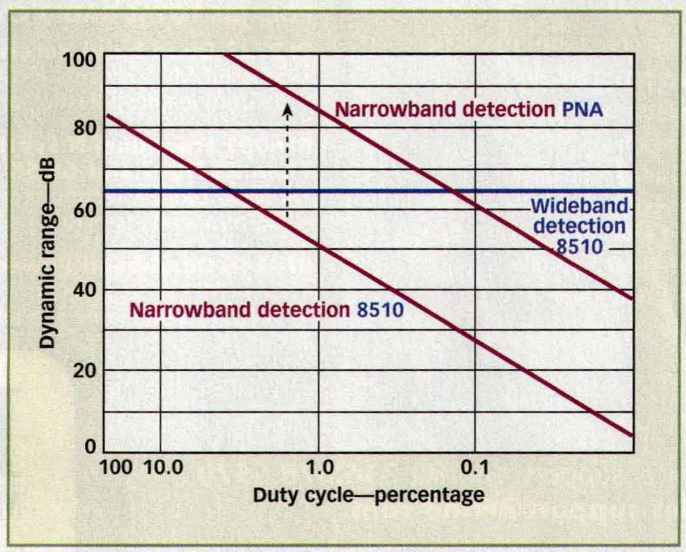
Measuring a component using the spectral-nulling technique requires modulation via control of the DUT bias or by a pulsed stimulus. **Figure 8** shows the hardware configuration for a pulsed-stimulus measurement. Gate switches (modulators) are placed in front of the source and receivers where the delay and width of each of these gates can be set up independently. This pulses the analyzers internal source and provides time gating for the receivers to do point-in-pulse and pulse profiling as the following section illustrates. The external modulators and pulse generators largely define



5. This plot demonstrates the spectral nulling of pulsed harmonics with a 500-Hz digital IF filter.



6. This is a time-domain representation of the spectral-nulling mode.



7. This plot shows the duty cycle loss using the spectral-nulling mode.

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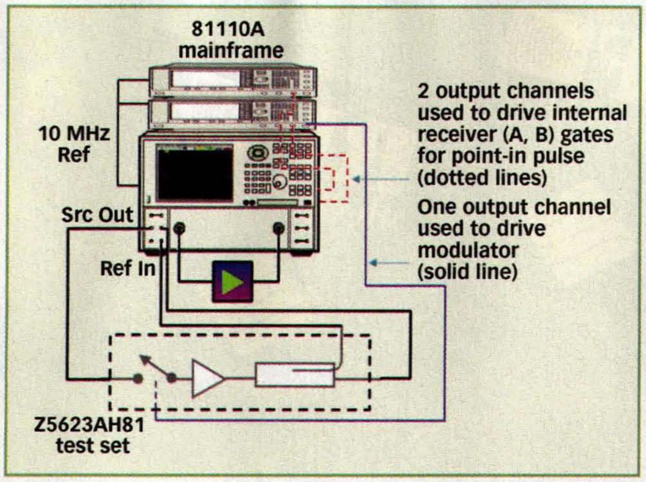
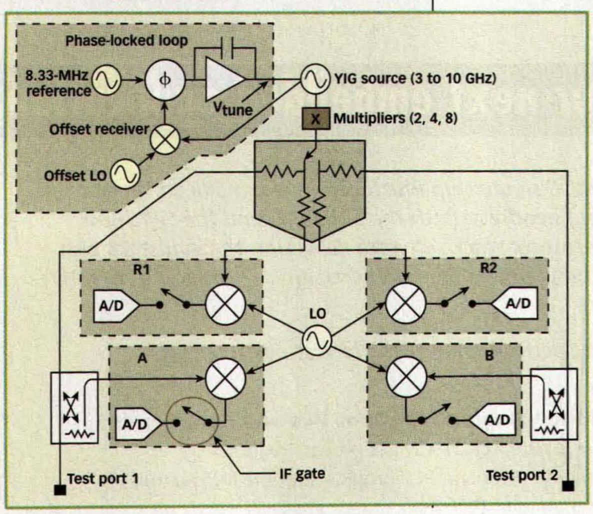
pulse-width limitations. The pulse generator must have a phase-locked-loop (PLL) reference (10 MHz) input to lock the analyzer and pulse generator to the same time base. This is essential to make sure that the frequency-domain components of the filter and pulsed spectrum are locked together during alignment of nulls with PRF components. The microwave PNA should be configured with options H08 and H11. Option H11 provides the IF gating hardware for point-in-pulse and pulse profiling. Option H08 provides application software to configure the analyzer in spectral-nulling mode.

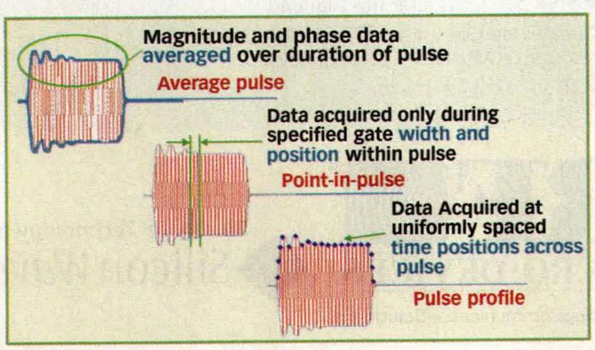


8. This hardware can be used for vector network analyzers with a pulsed stimulus.

In this configuration, an external coupler is used to couple back the pulsed source signal to the reference receiver **(Fig. 9)**. This is beneficial when measuring ratioed parameters because any deviations in the external components after calibration will have minimal affect on the measurement results. Both the measurement and reference receiver will see the same deviations. A modulator is placed after the source and must have a frequency response equal to the DUT requirements (i.e., it must be able to pass the signal from the source with minimum attenuation). An amplifier may be placed after the modulator to provide a constant source match during measurement and calibration, and may also be used to increase the pulsed signal power. An isolator may be required (before the modulator) to isolate the analyzer source from the modulator, so that when the modulator is in the off state (no energy passing through modulator) that any high reflections, due to the off-state match of the modulator, are minimized before reaching the analyzer. A highpass filter may also be required (after the modulator) to filter out any video feedthrough, generated by the modulator, which may interfere with the operation of the analyzer.



9. PNA IF gating can be used for point-in-pulse/pulse-profiling.



10. These are three examples of pulse-response measurement types.

There are three different pulse-response-measurement types that may be used to determine pulse characteristics **(Fig. 10)**. Any of these can be used with either the synchronic-pulse-acquisition or the spectral-nulling techniques by utilizing receiver gating in the microwave PNA. Receiver gating is implemented by adding IF gates (switches) after the first converter. These gates are TTL controlled and provide the hardware ability to perform point-in-pulse and pulse-profiling by providing a delay and width for the incoming pulsed RF signal.

- Average-pulse measurements are performed by not applying any receive triggering delay or gating. This means that the receiver measures and integrates all the energy from the DUT during the pulse duration. In effect, the gate width is set equal to or greater than the pulse width.
- Point-in-pulse measurements provide the user the ability to measure the output of the DUT at any point in time during the pulse by applying a time delay between when the source/bias is pulsed and when the receivers start taking data. A time gate width for which the pulsed energy is allowed to pass to the receivers can also be specified providing a variable receiver integration window.
- Pulse-profiling is similar to point-in-pulse except that the measurement information is displayed in time domain, at a CW frequency, where the time axis represents a point-in-pulse measurement with a variable time delay (i.e. from a starting delay to a stop delay). This can be thought of as walking the point-in-pulse measurement across the envelope of the pulse. With the microwave, PNA the minimum receiver gate width is approximately 50 ns resulting in excellent resolution for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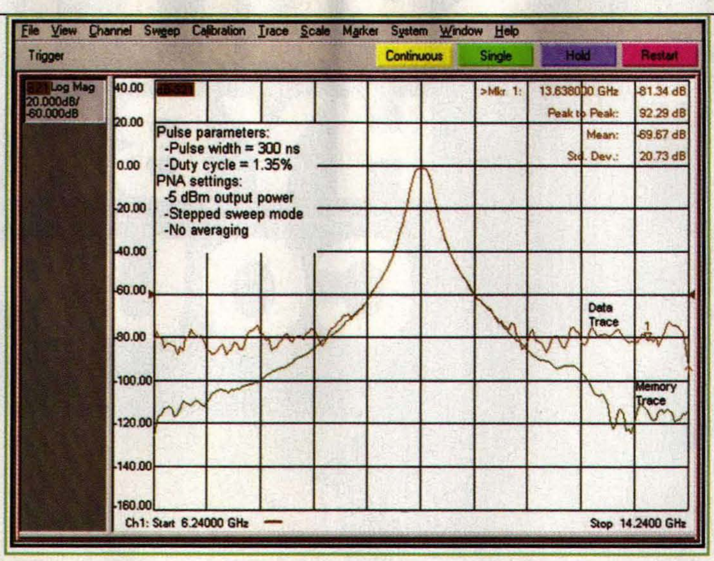
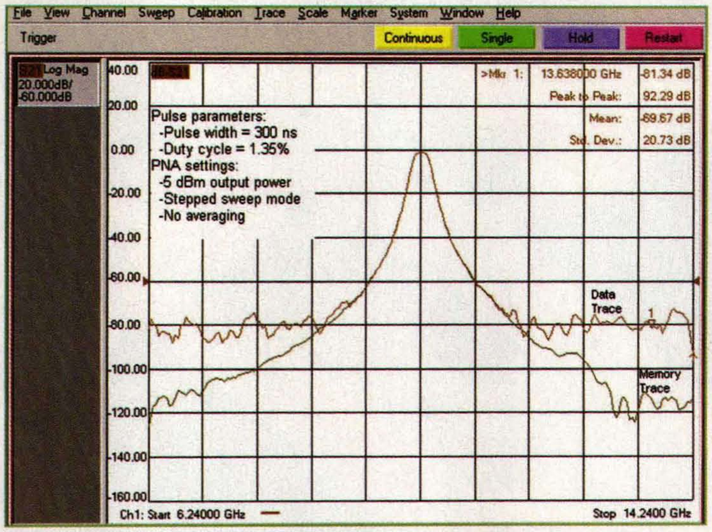
pulse-profiling analysis.

Figure 11 shows an S-parameter filter-measurement comparison between a signal with no pulsing (memory trace) and a signal with a 300-ns pulse width (data trace) both at similar IF bandwidth settings. For a 300-ns pulse width, the spectral nulling mode was used. With 1.35-percent duty cycle, the specified dynamic range has been effectively reduced by 37.4 dB [20log(duty cycle)]. This can be visualized by comparing the rejection of the memory trace with that of the data trace at the marker. The data trace is showing a stop-band rejection figure of approximately 80 dB. The memory trace is showing rejection of approximately 115 dB which is a 35-dB difference corresponding to the 37.4 dB duty cycle loss. If needed, 10 dB [10log(number of averages)] can be added by applying 10 averages to the measurement **(Fig. 12)**.

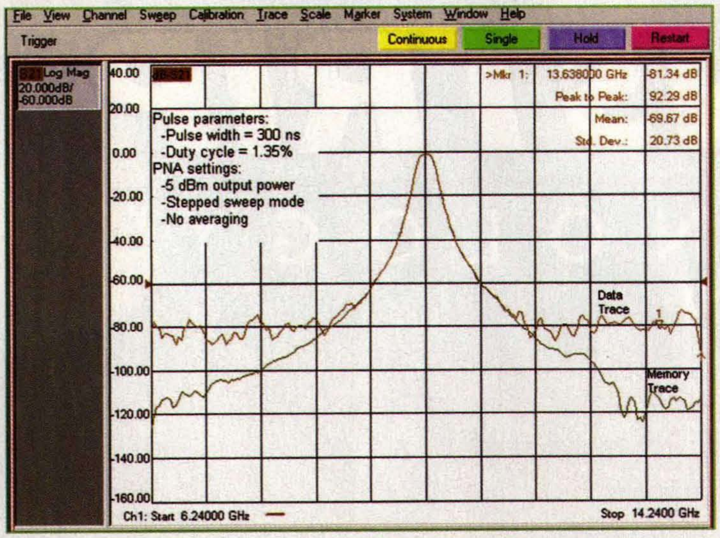
With a 300-ns pulse width and 1.35-percent duty cycle, the PRF is 45 kHz. This means that the first PRF tone is 45 kHz away from the fundamental. **Figure 13** shows a similar measurement using the same 1.35-percent duty cycle, but with a pulse width of 5 μs. In this case, the PRF is 2.7 kHz which places a PRF tone much closer to the fundamental tone. Narrowband detection techniques may have difficulties filtering a tone this close to the fundamental. However, the spectral-nulling technique has no difficulties nulling out this tone resulting in an accurate measurement. The duty cycle loss is expected to be the same for the 300-ns and 5-μs pulse-width examples because the duty cycles are the same. In Figs. 11 and 13, this is evident in that the rejection regions for both examples are the same at approximately 80 dB. In performing the measurements described in these examples, it should be noted that the Agilent E8362/3/4B and E8361A analyzers should be configured with option H08 and H11 if using the spectral-nulling technique and/or if point-in-pulse/pulse-profiling is required. MRF



11. This plot shows the spectral-nulling mode with a 300-ns pulse width, 1.35-percent duty cycle, and no averaging.



12. This plot shows the spectral-nulling mode with a 300-ns pulse width, 1.35-percent duty cycle, and 10 averages.



13. This plot shows the spectral-nulling mode with 5-μs pulse width, 1.35-percent duty cycle, and no averaging.

FOR FURTHER READING

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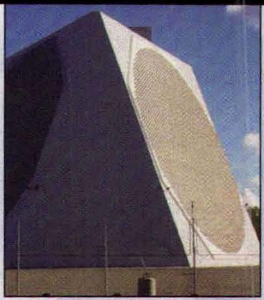

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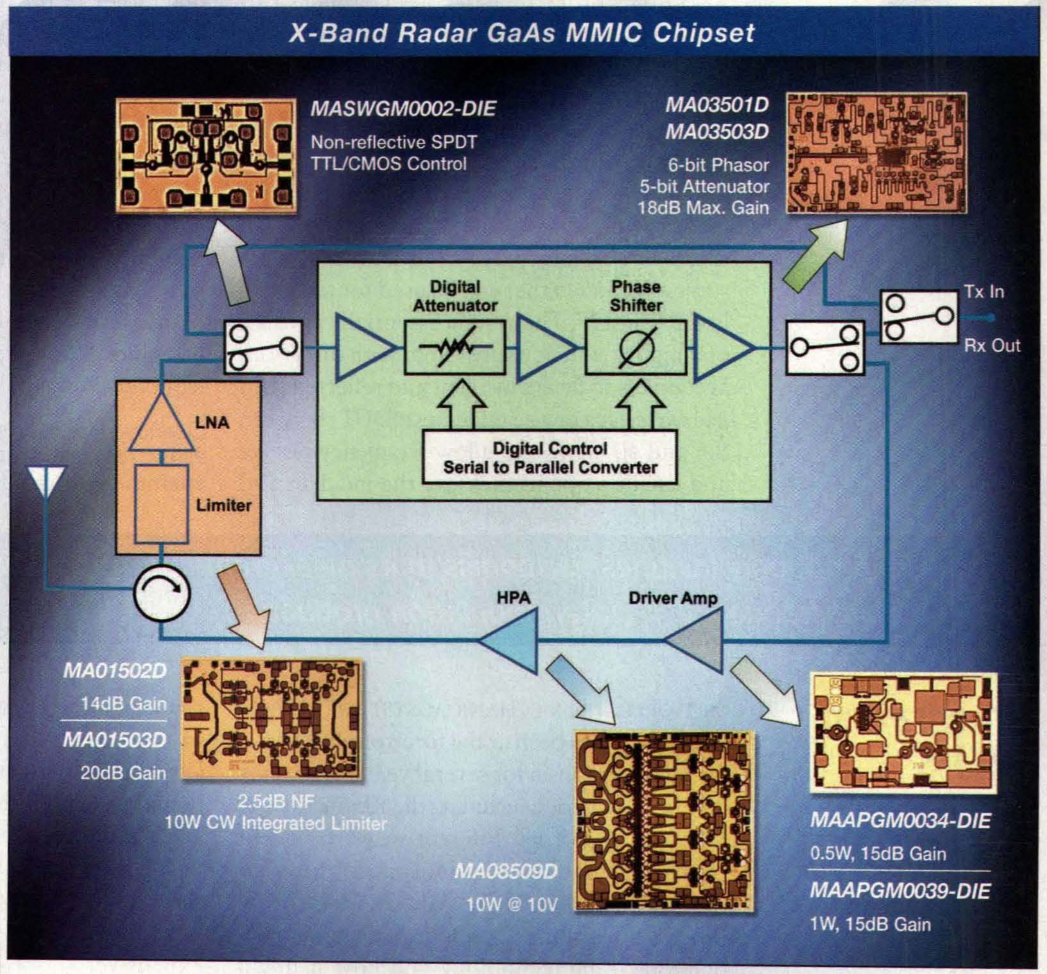

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Analyze The Effect Of Envelope Impedance On IMD

IMPEDANCE MATCHING plays a major role in realizing optimum performance from high-power amplifiers, especially in digitally modulated communications systems. Fortunately, an application note from Celeritek (Santa Clara, CA), "Study of the effect of envelope impedance on intermodulation asymmetry using a two-tone time domain measurement system," provides details on a test system that can be used to evaluate different active devices under various conditions of source and load impedance matching. The system not only includes harmonics in its measurements, but also takes into account intermediate-frequency (IF) intermodulation products.

The four-page note, which is available for free download from the company's website, details an active source- and load-pull measurement system that can be used for testing at low RF and IF. The system essentially consists of a high-frequency subsystem with directional couplers to detect incident and reflected voltage waves at a device under test (DUT) between 0.5 and 40 GHz, and a low-frequency test set and oscilloscope to measure the incident and reflected voltages between 200 kHz and 100 MHz.

As an example, measurements were performed on a heterojunction-bipolar transistor (HBT) biased for Class B operation at +3.5 VDC. Two-tone measurements were performed with 830- and 840-MHz signals; power sweeps were performed while actively load-pulling the device's lower 10-MHz IF component. A series of measurements were performed while the magnitude of the IF reflection coefficient was held constant at unity and the phase was varied from 0 to 360 deg. in 20-deg. steps.

As the measurements show, the IF impedance significantly affects the maximum efficiency and output power. For example, the output power and efficiency are dramatically reduced as the IF impedance approaches an open circuit. Similarly, the phase of the IF reflection coefficient has a significant effect on the asymmetry of the third-order intermodulation distortion. For more details, download a copy of the note from the company's website.

Celeritek, Inc., 3236 Scott Blvd., Santa Clara, CA 95054; (408) 986-5060, FAX: (408) 986-5095, Internet: www.celeritek.com.

The system not only includes harmonics in its measurements, but also takes into account intermediate-frequency (IF) intermodulation products.

Integrating MEMS Technology Into Existing Processes

MICROELECTROMECHANICAL SYSTEM (MEMS) technology has been at the forefront of various technical symposia for several years with many different industries, including the RF/microwave industry, exploring different ways to benefit from the technology. A white paper from Ziptronix (Morrisville, NC), "MEMS: Mainstream Process Integration," provides a general introduction to the technology and how it might work with existing integrated-circuit (IC) processes, along with the special capabilities offered by Ziptronix to help integrate MEMS with traditional IC technologies.

As the white paper points out, ICs can be thought of as essentially planar (or flat) while MEMS are typically fabricated in three dimensions. While ICs depend on electron effects buried beneath their surfaces, MEMS are essentially surface-effect devices. Also, ICs are passivated while still in wafer form in order to protect them from the effects of outside environments. In wafer form, MEMS devices are extremely sensitive to the outside environment until they are safely packaged. Because of this sensitivity, MEMS must be handled very carefully during all post-foundry steps, including wafer dicing, placement in a package, formation of electrical contacts, and sealing of the package. Because of the care required, the handling and packaging of MEMS devices is far different from that of ICs, and can be quite expensive.

The seven-page white paper describes a proprietary room-temperature covalent bonding process called ZiROC™ which allows the formation of a permanent bond between semiconductor materials, such as silicon wafers, and carrier substrates, such as glass. Materials to be bonded are processed by chemo-mechanical polishing to establish a planar surface, and then the use of a proprietary process to active one or both of the surfaces to create the covalent bond. For a copy of the white paper, contact:

Ziptronix, Inc., 800 Perimeter Park Dr., Suite B, Morrisville, NC 27560; (919) 459-2400, FAX: (919) 459-2401, Internet: www.ziptronix.com.

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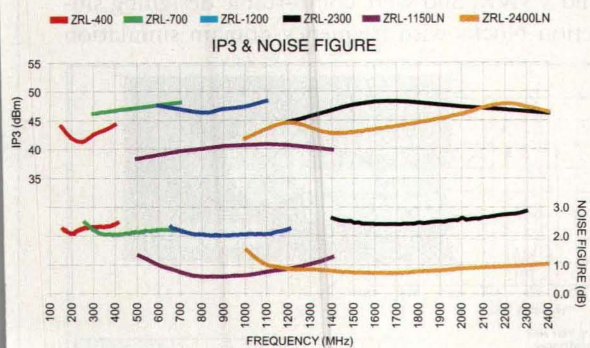

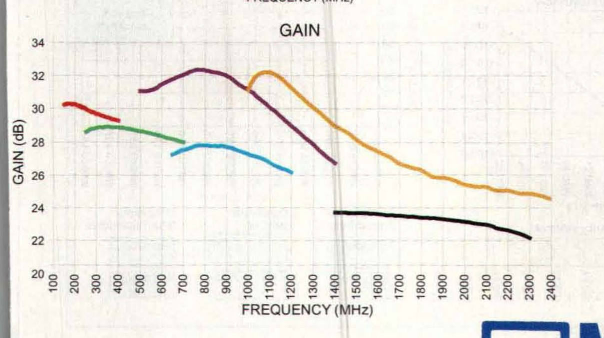

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ZRL-2300	1400-2300	24	2.5	46	24.6	119.95
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cover story

RF Design Environment Closes Verification Gap

JACK SIFRI AND MOUNIR ADADA
Product Managers
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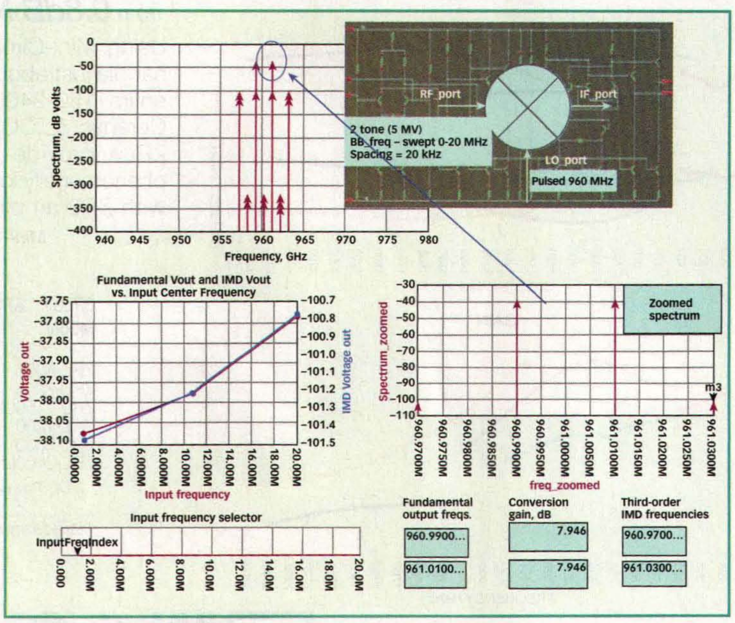
When integrated with industry-standard IC schematic and layout tools, this powerful suite of RF design and verification programs can improve the efficiency of the integrated-circuit design process.

Design verification requires a full suite of circuit and device models, analysis tools, and simulated measurement capabilities. The RF Design Environment (RFDE), introduced in September 2002 as the first product developed as part of the alliance between Agilent Technologies (Santa Rosa, CA) and Cadence Design Systems (San Jose, CA), brought frequency-domain circuit simulation technology to mainstream silicon RF/analog/mixed-signal designers. Using tools long familiar to microwave designers, including harmonic-balance and circuit-envelope simulators, these silicon integrated-circuit (IC designers) were brought one step closer to true verification within the Cadence IC design flow. Now, with the release of RFDE 2003C, the second product from that alliance, the gap between RF circuit/system design and verification closed even further in two key areas: system-level verification of RF circuit performance to wireless standards, and physical-level modeling of high-frequency components and interconnects in the layout of an RF IC.

With RFDE 2003C, wireless IC designers can now directly verify Cadence-based RF circuit schematics with modulated sources and measurements and pre-configured wireless test benches (WTB) based on current wireless standard specifications. Also, Cadence users can now generate accurate electromagnetic (EM) based models of passive on-chip components and interconnects using Momentum, a 2.5D method-of-moments-based simulation technology. These EM-based models are then simulated directly in the Cadence circuit schematic without the usual conversion to approximate lumped-element models, providing much greater accuracy for wireless and high-speed wire-line applications.

Traditionally, RF and microwave designers were concerned with frequency-domain data such as S-parameters, power gain, output power at 1-dB compression (P1dB), noise figure, third-order intercept point (IP3), and VSWR, and were comfortable designing single function blocks with frequency-domain simulation



1. These images show how the Harmonic Balance simulator tackles an analysis of mixer two-tone intermodulation distortion (IMD).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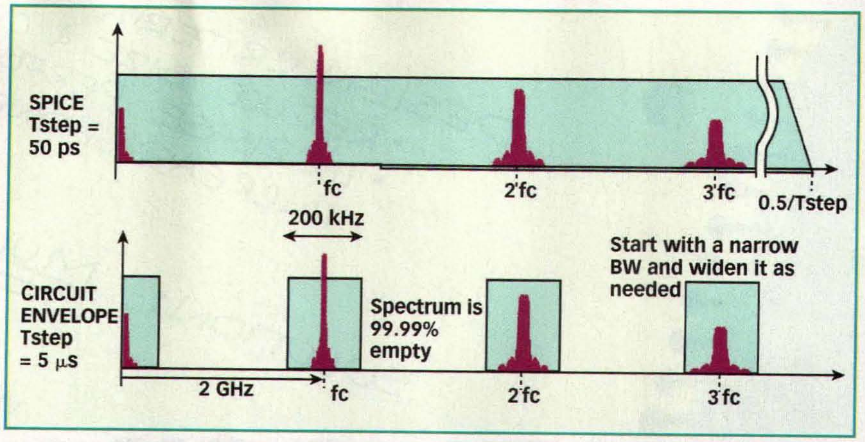
tools. Analog/mixed-signal designers, on the other hand, were accustomed to using SPICE for data such as voltage gain, AC sweeps of voltage gain and impedance, and noise voltage. However, because of the need to meet tighter time-to-market schedules, modern analog/mixed-signal IC designers need these simulators in one environment. To perform a full design and analysis, frequency-domain simulation is a vital complement to time-domain simulation. The RFDE 2003C environment provides frequency-based simulators from within the industry-standard Cadence design environment.

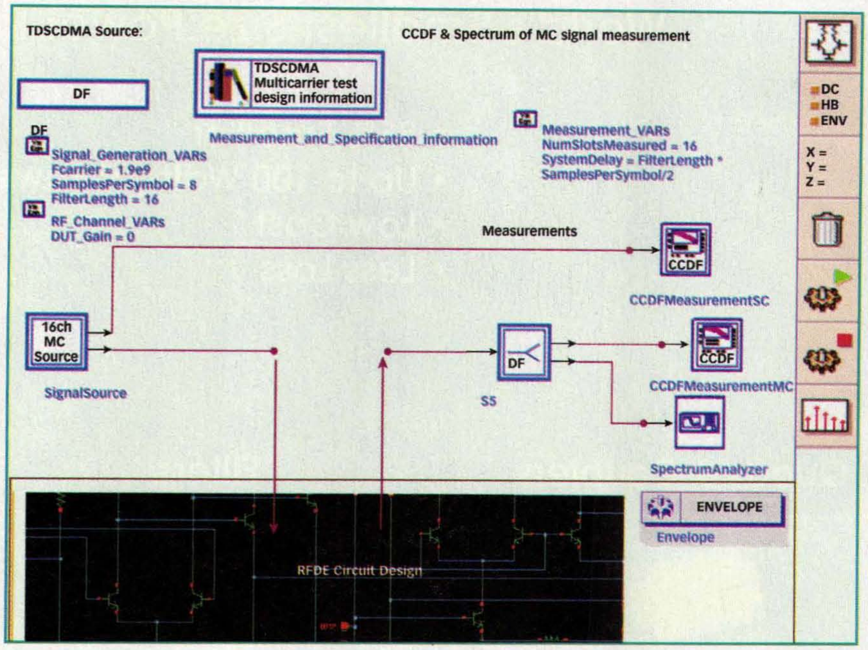
Harmonic Balance (HB) is a nonlinear frequency-domain simulator that rapidly analyzes multiple independent signals, no matter how closely spaced in frequency. Amplifier compression, harmonic distortion, oscillator spurious effects, phase noise, and mixer inter-modulation products are some of the analyses that HB is especially well suited for. The HB simulator from Agilent is a stable and robust technology that has benefited from continuous enhancements, making it the ideal analysis tool for large and highly nonlinear RF ICs. Enhancements include access to two different solvers (Direct and Krylov), three advanced pre-conditioners, memory waveform reduction techniques, and other advanced techniques (such as transient-assisted Harmonic Balance) for solving highly nonlinear circuits with digital content. Because it is a frequency-domain technique, distributed models are easily and accurately included. The HB simulator is most suitable for circuits with two or more large signal tones (multiple tones, frequency translation, mixers, detectors, multipliers). Frequencies need not be coperiodic. It is also well suited for high-Q circuits, dispersive circuits, ideal delays, transmission lines, microstrip lines, and N-port networks.

For example, **Fig. 1** shows a two-tone simulation on a mixer with 960-MHz local-oscillator (LO) frequency and 20-kHz separation of two tones centered at 1 MHz and swept from 1 to 20 MHz while maintaining the 20-kHz separation. Simulation outputs were extracted in less than 2 min. Output data includes output spectrum, conversion gain, and second and third-order intermodulation distortion (IMD). The same simulation would take at least 1000 times longer using a time-domain SPICE-type simulator.

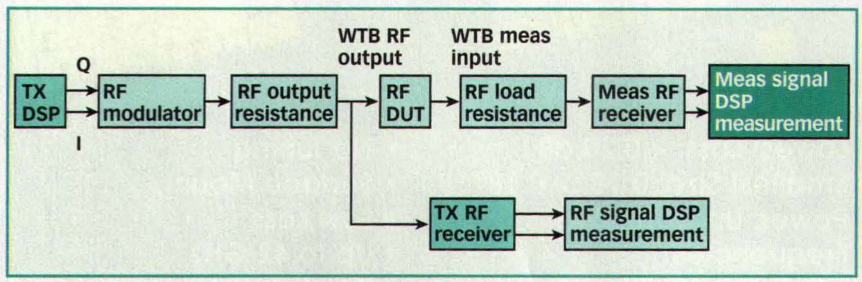
In highly nonlinear analog and RF circuits that might include flip-flops, switching devices, and frequency dividers, the HB simulator employs an advanced



2. The simulation efficiency of the Circuit Envelope simulator is compared here with SPICE.



3. Wireless test benches integrate Agilent Ptolemy simulation with analog/RF circuit envelope simulation in the Cadence flow.



4. This block-level representation of a WTB shows the architecture for a wireless transmitter and receiver.

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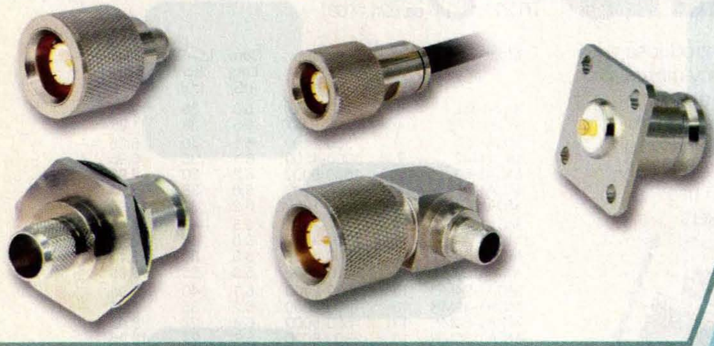

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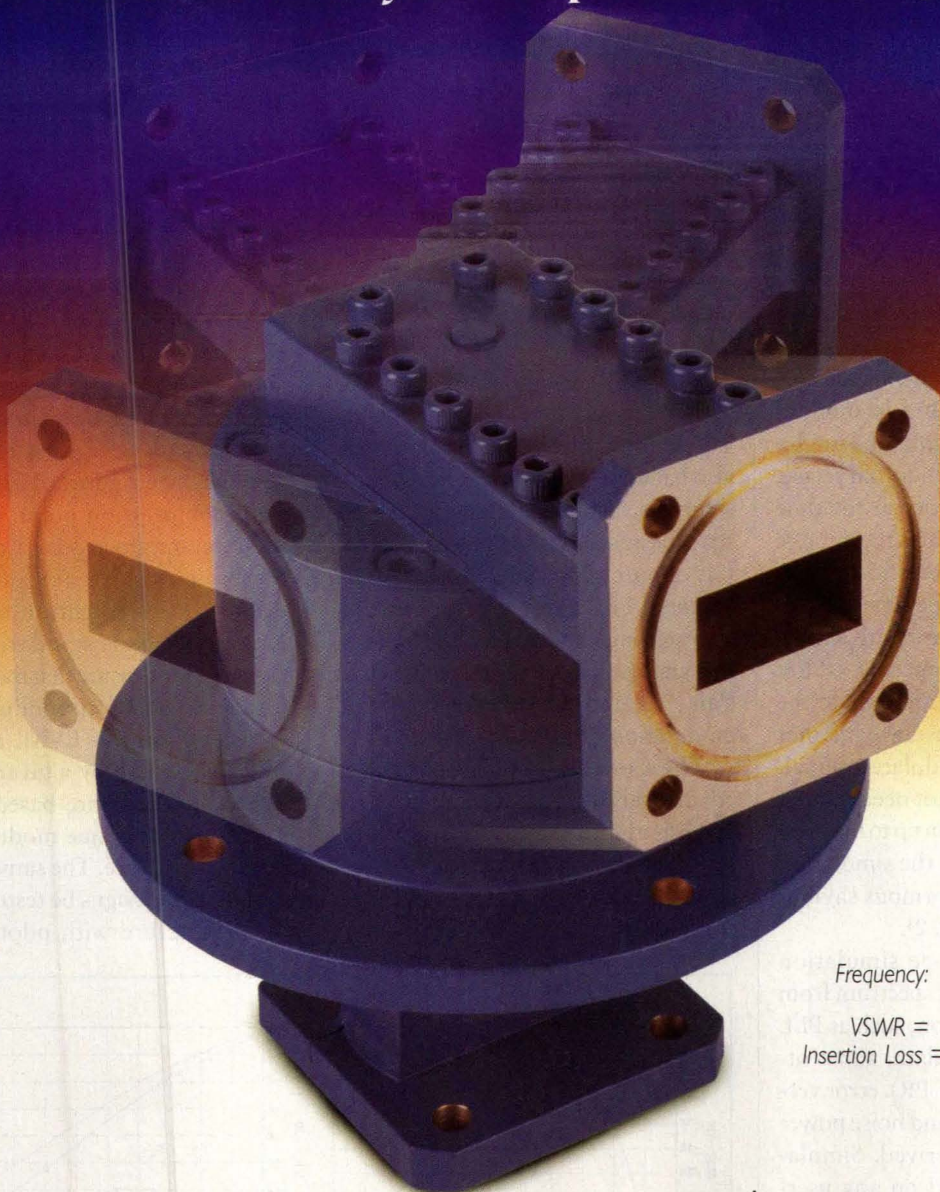

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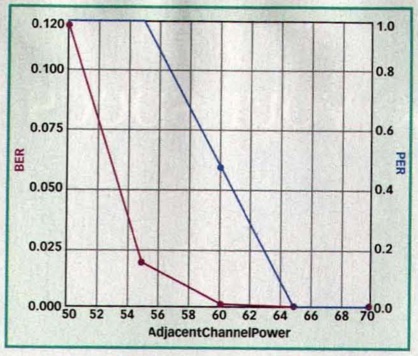
technique called transient-assisted HB (TaHB) to obtain a solution. First, a short transient simulation is run until a steady state output is reached. The solution is then transformed to the frequency domain and used as an initial guess for the HB simulator to converge into the final solution. In this case, output data include waveform, spectrum, and phase-noise plots, not available from just a time-domain simulation.

The Circuit Envelope (CE) simulator is a mixed-domain simulator that efficiently analyses pseudorandom, digitally modulated signals found in modern wireless circuits. It samples the modulation envelope (amplitude and phase, or I and Q) of the carrier in the time domain and then calculates the discrete spectrum of the carrier and its harmonics for each envelope time sample. The main advantage of its mixed-frequency/time-domain approach is that it performs the simulation only in the relatively narrow frequency band that is occupied by the modulated signal. Unlike SPICE, it does not need to analyze the complete spectrum up to the maximum frequency set by the simulation period, resulting in enormous savings of calculation time **(Fig. 2)**.

The Circuit Envelope simulation output is a time-varying spectrum from which useful information, such as PLL frequency versus time data, adjacent-channel power ratio (ACPR), error vector magnitude (EVM), and noise power ratio (NPR) can be derived. Simulations can be performed on any user-specified orders of harmonics (5th, 7th, 9th, etc.), and all analyses can be carried out down to the transistor level. This simulator is well suited for analyzing I/Q modulators for such characteristics as modulation accuracy, frequency response, undesired leakage, IMD terms, efficiency, output power, modulator amplitude and phase accuracy, and EVM. Many of these analyses and simulations would be almost impossible to complete with a purely time-domain simulator such as SPICE. Other Circuit Envelope applications include pulsed signals, harmonic behavior during transient time, pseudorandom digitally

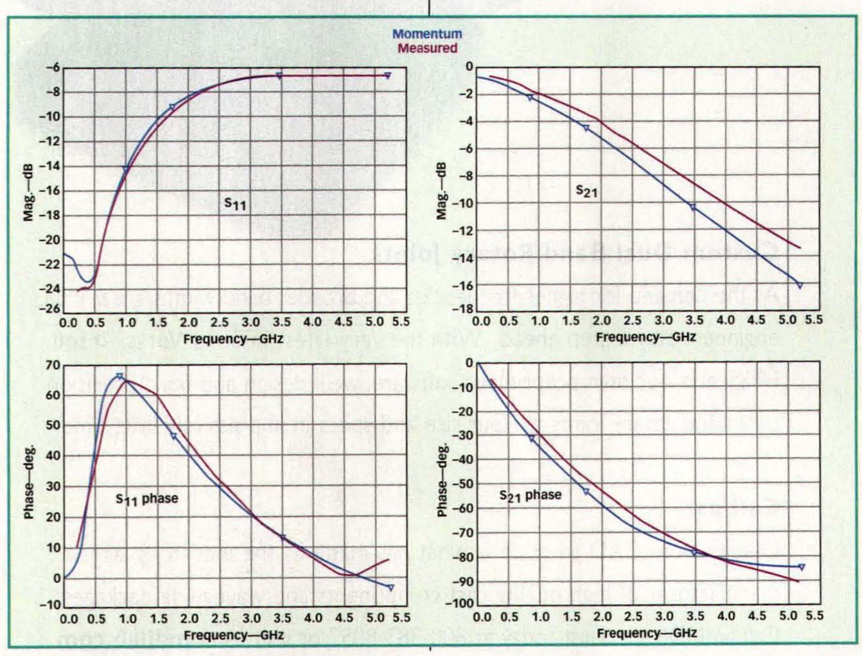


5. This output plot reports BER and PER results as functions of adjacent-channel power.

modulated RF solutions, ACPR, EVM, and PAE simulation and optimization. The Circuit Envelope simulator can also handle a wide range of transient RF solutions, including PLL frequency versus time analysis (PLL lock time), analysis of automatic-gain-control (AGC) circuitry, PLL transient response (ringing, settling, and overshoot) simulation and optimization, and higher-order (5th, 7th, and 9th order) mixer intermodulation product analysis.

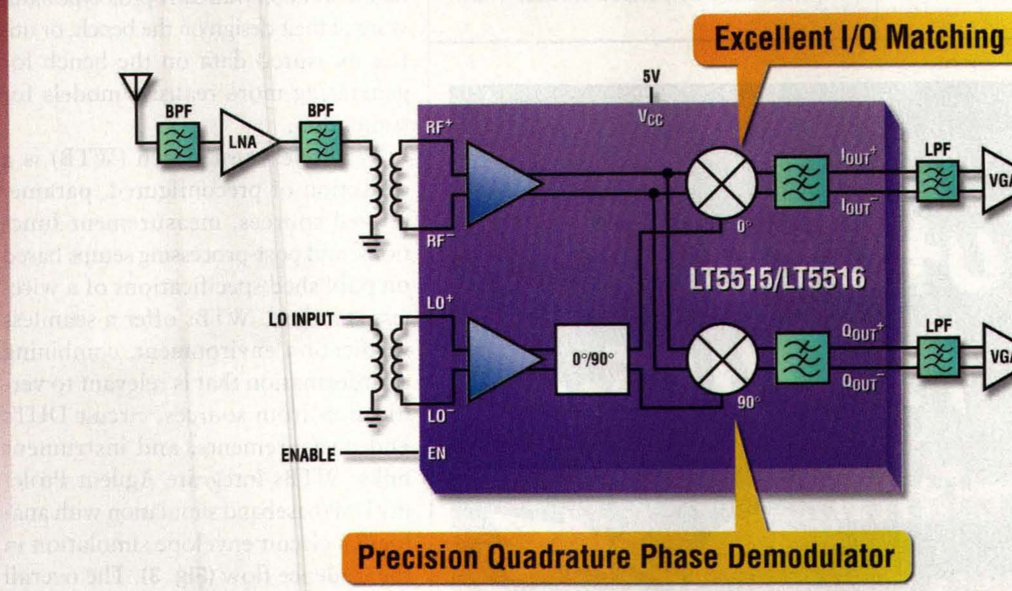
The Convolution simulator is an advanced time-domain simulator that extends the capability of traditional transient analysis by accurately simulating dispersive, frequency-dependent components such as transmission lines and S-parameters. Convolution is best applied to baseband transient signals in the presence of distributed elements or frequency-domain models (dispersive circuits, ideal delays, transmission lines, microstrip lines, and N-port networks). Because both HB and CE results are in the spectral frequency domain, it is fast and easy for both simulators to process these spectral components and effectively optimize key results such as distortion and spurious signals (–1 dB compression, IP3, ACPR). Time-domain simulators are better suited to optimization of time-domain quantities.

Traditional RF tests rely only on discrete-tone figures of merit such as 1-dB compression point, third-order intercept, and group delay. Unfortunately, these metrics are not adequate for design and verification of complex modern wireless standards. The RF designer must ensure that the design performs according to modulated measurements such as EVM, ACPR, and BER, as defined by a given standard. These standards are based on waveforms with a unique modulation and framing structure. The same standards require that designs be tested based on burst structure with pilot, idle, and

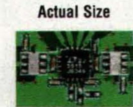


6. High-frequency component models based on EM simulation approach the accuracy of measured data, as shown by this spiral inductor data. Momentum cells can be freely integrated for use in Cadence Composer.

High Linearity Direct Conversion Receivers



Actual Size



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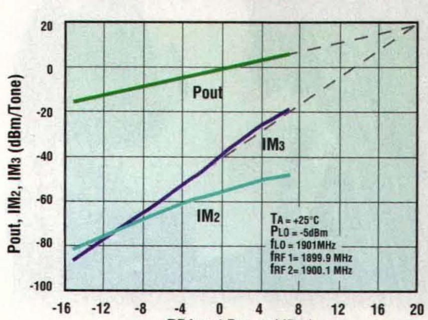
Noise Figure	16.8 dB	12.8 dB
Conversion Gain	-0.7 dB	4.3 dB
LO-RF Leakage	-46 dBm	-65 dBm
LO Drive Level	-5 dBm	
Supply Voltage	5V	
Package	4mm x 4mm QFN	

I/Q Output Power, IM2, IM3 vs RF Input Power



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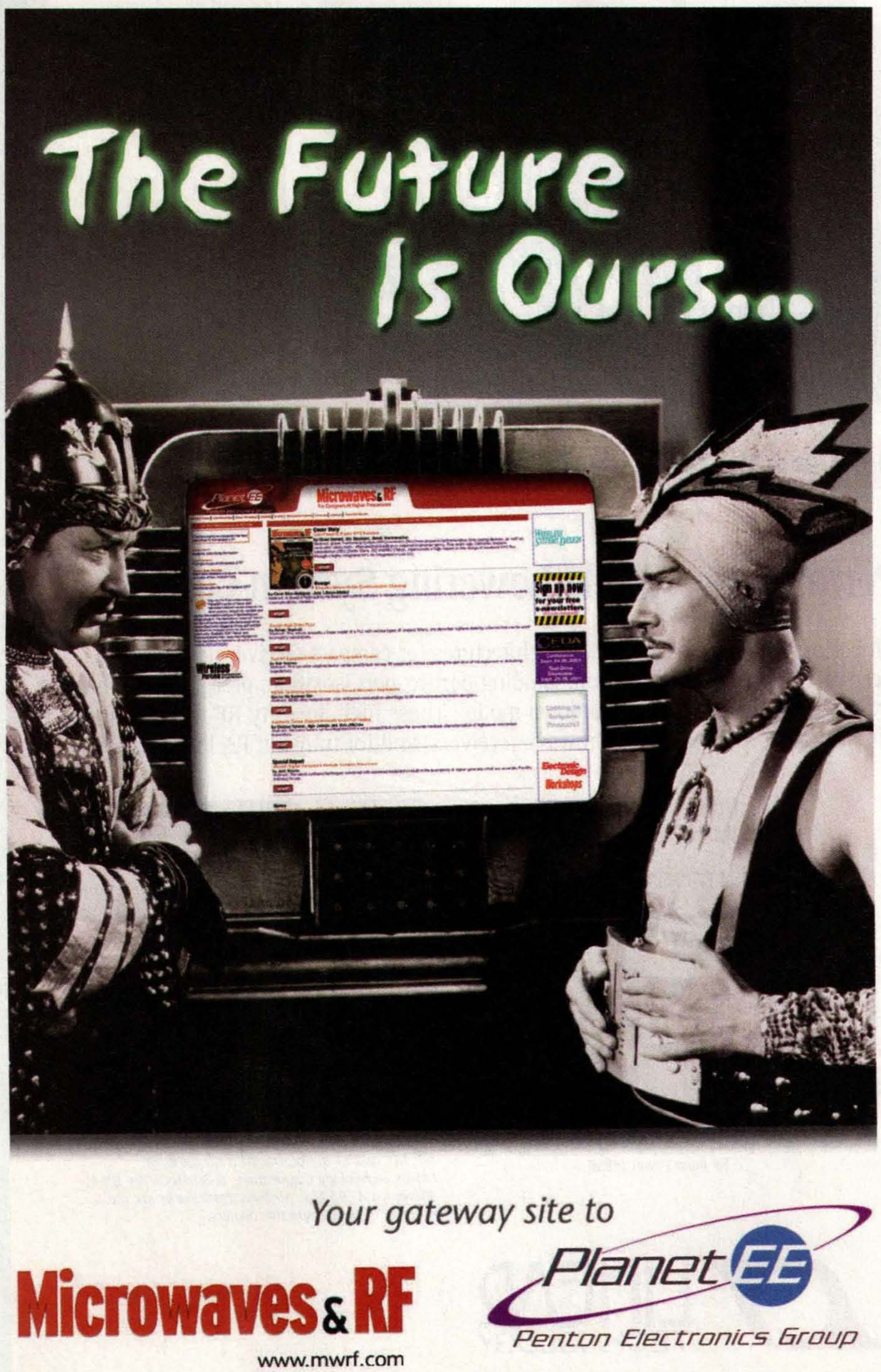
active portions, and with measurements specific to a portion or on the composite waveform. Often these measurements require meeting specifications for different data rates and sometimes need resolution at the bit level, requiring fully compliant parameterized sources and measurements.

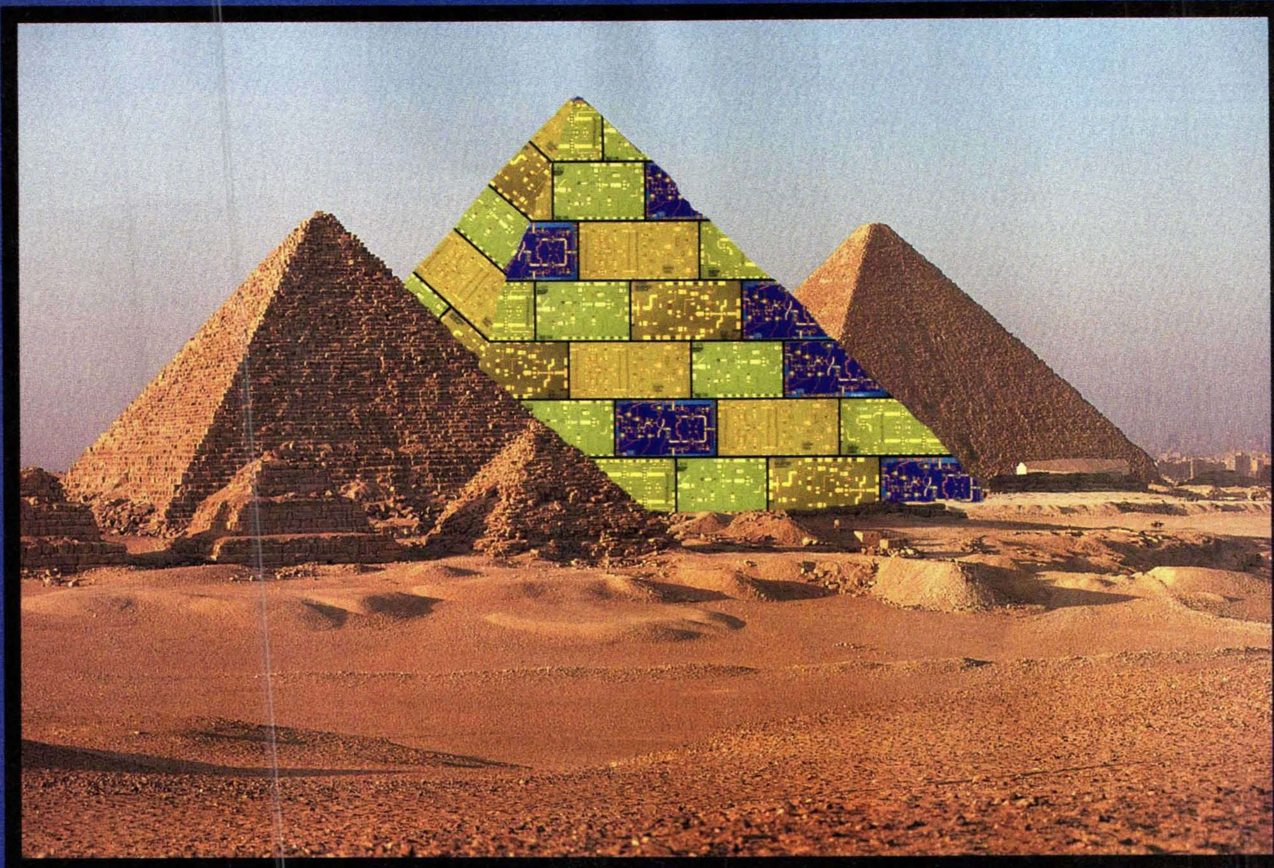
RFDE 2003C addresses this need with a collection of preconfigured test benches for testing a complete circuit design, as well as wireless sources and measurement expressions which can be positioned at desired nodes. Wireless test benches take the verification challenge one step further by providing connectivity to physical test instruments from Agilent Technologies. Through this instrument connectivity, a circuit designer can compare the virtual verification with early prototype hardware of their design on the bench, or utilize measured data on the bench for generating more realistic models for simulation.



A wireless test bench (WTB) is a collection of preconfigured, parameterized sources, measurement functions, and post-processing setups based on published specifications of a wireless standard. WTBs offer a seamless verification environment, combining all information that is relevant to verification from sources, circuit DUTs and measurements, and instrument links. WTBs integrate Agilent Ptolemy DSP/baseband simulation with analog/RF circuit envelope simulation in the Cadence flow **(Fig. 3)**. The overall block level representation of a WTB for both transmitter and receiver scenarios includes sources and measurements at RF and DSP levels **(Fig. 4)**. In addition, the Circuit Envelope (CE) simulator in RFDE 2003C contains a new Automatic Verification Modeling (AVM) option to aid simulation of large and complex ICs, allowing computationally intensive BER/PER simulations on large circuits.

Because wireless standards require specific tests, RFDE 2003C includes an extensive set of pre-configured test benches. The preconfigured test benches are for wireless-local-area-network (WLAN), TDSCDMA, and 3GPP formats. In addition, new test benches can be generated and exported from Advanced Design System, making them available to circuit designers for testing and verification.

As an example, simulations of WLAN, PER, and BER measurements were performed on a circuit design of an existing commercial amplifier (MGA 545P8 from Agilent Technologies). The small, low-power amplifier is well suited for 5-GHz WLAN applications, and BER/PER values as a function of adja-



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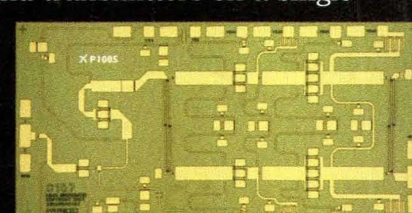

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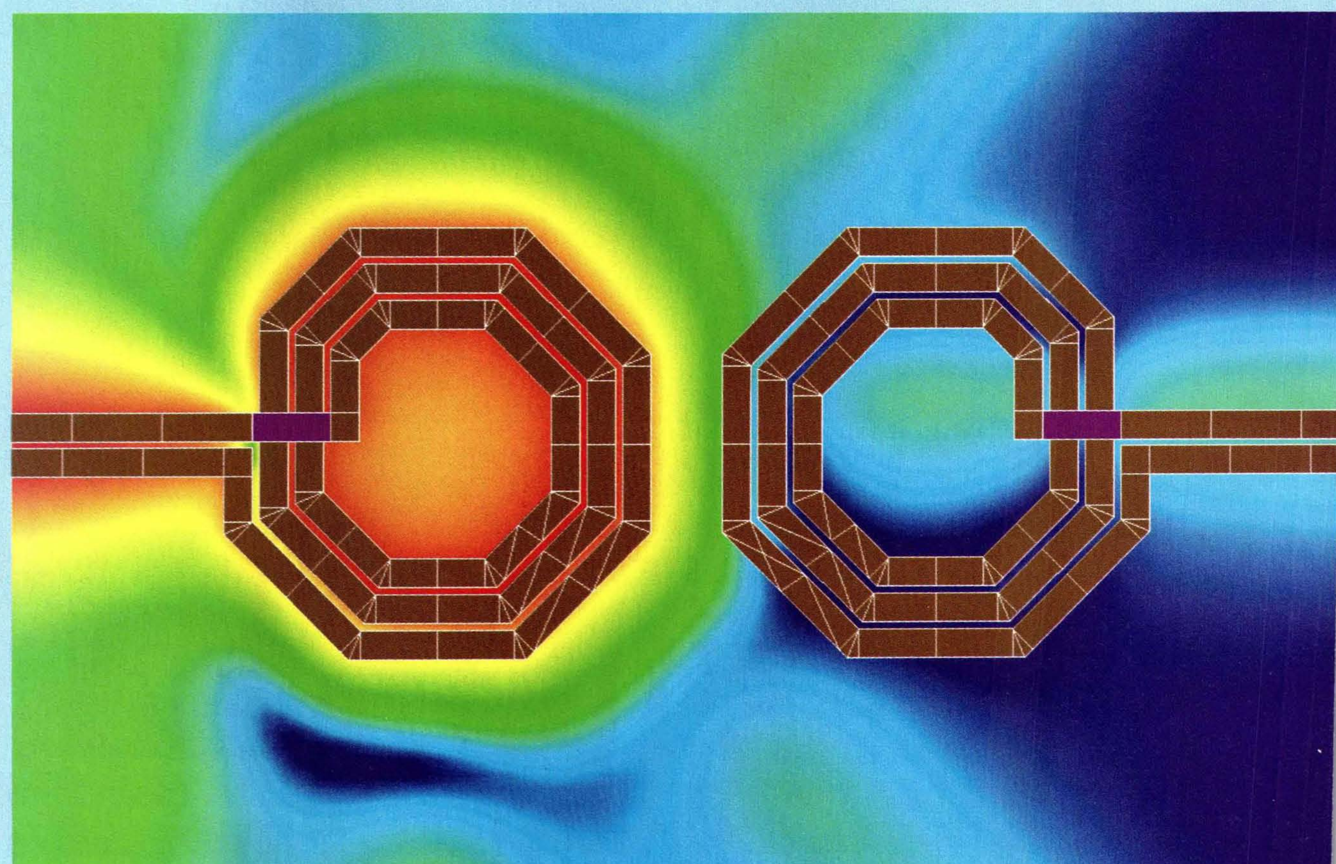

This is not a pair of fashion eye-glasses. It is the near field distribution on two coupled octagonal spiral inductors in RFIC visualized on the modern EM simulator, the IE3D Version 10. RFICs involve lossy and thin substrates, arbitrar angled and thick traces, and strong 3D structures. They are tough EM problems. However, they are easy for the IE3 You certainly can do much more with this highly capable and accurate simulator with optimization and synthes capabilities. For more information, please visit our web or contact us directly.

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cent-channel power were of particular interest. Preconfigured test setups were employed once the amplifier's supporting circuit design was ready. WLAN technology (IEEE 802.11a) was selected with a test bench for receiver adjacent-channel rejection. Default values were used for the test source parameters, including 5.2-GHz carrier and 54-Mb/s data rate, source signal bandwidth of 20 MHz, source power of –62 dBm, and variable adjacent-channel power at an adjacent-channel offset of 20 MHz. The simulation time step was set to 1/20 × 8) μs with the AVM option selected. A simulated sweep of adjacent-channel power from –50 to –70 dBm was then performed.

The simulation took less than 10 min per BER/PER point on a Hewlett-Packard computer workstation. **Figure 5** shows the BER and PER results as a function of adjacent-channel power. Using these results, one can be more confident of the system-level performance of the circuit design. This process can be repeated as the design size grows with the addition of other modules.

The RFDE 2003C tool also allows Cadence users to generate accurate EM-based models of passive on-chip components and interconnects using Momentum, Agilent's 2.5D EM simulator. With RFDE 2003C, Momentum is integrated into the Cadence Virtuoso (layout) environment, allowing Cadence users to perform EM modeling on select Virtuoso cell(s) as well as physical verification of critical nets **(Fig. 6)**. Full integration into the Virtuoso environment allows designers to extract Momentum cell(s) and back-annotate the EM results to the Cadence schematic.

Momentum computes S-parameters for general passive circuits, including microstrip, stripline, coplanar waveguide, and other topologies. Vias and air-bridges connect topologies between layers, so designers have used Momentum for years to simulate multilayer RF/microwave ICs, printed-circuit boards (PCBs), hybrids, multichip modules, and ICs. Momentum Visualization provides a three-dimensional perspective of simulation results, including viewing and animating the simulated current flow in conductors.

Traditionally, critical passive elements, such as spiral inductors, have been modeled using simple RLC networks. However, with the resistive loss in the metallization of the spiral coils, the resistivity of the silicon substrate and capacitive coupling effects to the substrate, inductors on silicon behave quite differently than ideal inductive components. With RFDE Momentum, successful design and simulation of wire-

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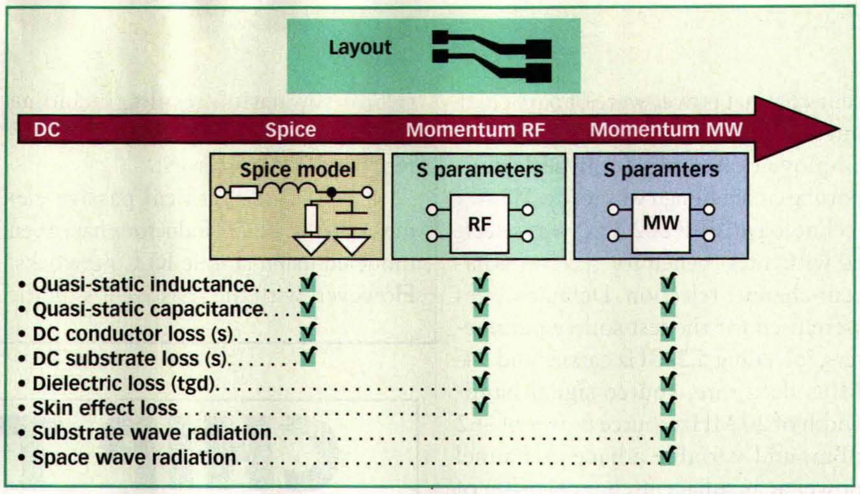
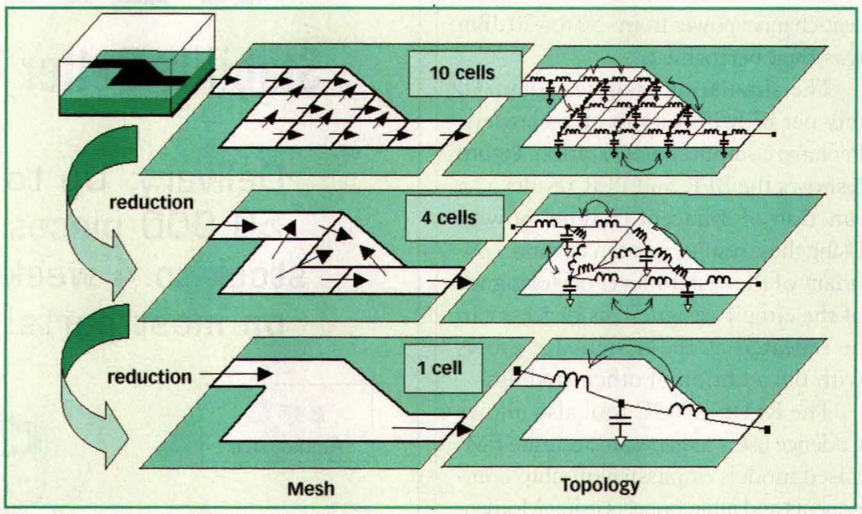
less RF ICs based on accurate characterization of the electrical behavior of these spiral inductors is possible. Momentum EM simulator models the critical physical parasitics, allowing RF IC designers to design spirals with maximum quality factor (Q) at the desired operating frequency, with the desired inductance value and available substrate "floor space."

The following steps describe a typical process for creating and simulating a design with Momentum. First, a substrate definition file is created and linked to the Technology File of the given process. The designer can then select a portion of the layout and create a "Momentum View." A Momentum simulation is then set up, and the designer can choose between two different modes of operation. Microwave mode suits designs requiring full-wave EM simulations that include microwave radiation effects, while RF mode is for designs that are geometrically complex, electrically small, and do not radiate. Momentum RF mode is also useful for quick simulations on new microwave models where radiation effects are not important, or where computer resource conservation is a priority. After the simulation is complete, the Momentum EM results are saved and can be back-annotated to the schematic (Cadence Composer) for circuit simulation with other passive/active circuit elements.

The Momentum (microwave) and Momentum RF modes use different Method of Moments technologies to produce S-parameter models for layout-based, physical designs. Momentum (microwave) uses fullwave electromagnetic functions based on Maxwell's equations that include substrate and space wave radiation effects. Momentum RF uses quasistatic electromagnetic functions based on low-frequency approximations, which excludes substrate and space-wave radiation effects. Although Momentum RF excludes radiation effects from its resulting models, both modes produce models that include these physical effects: quasistatic inductance, quasistatic capacitance, DC conductor loss, DC substrate loss,



7. The RF and microwave analyzer power of Momentum provides more key calculated parameters than those calculated with a SPICE model.



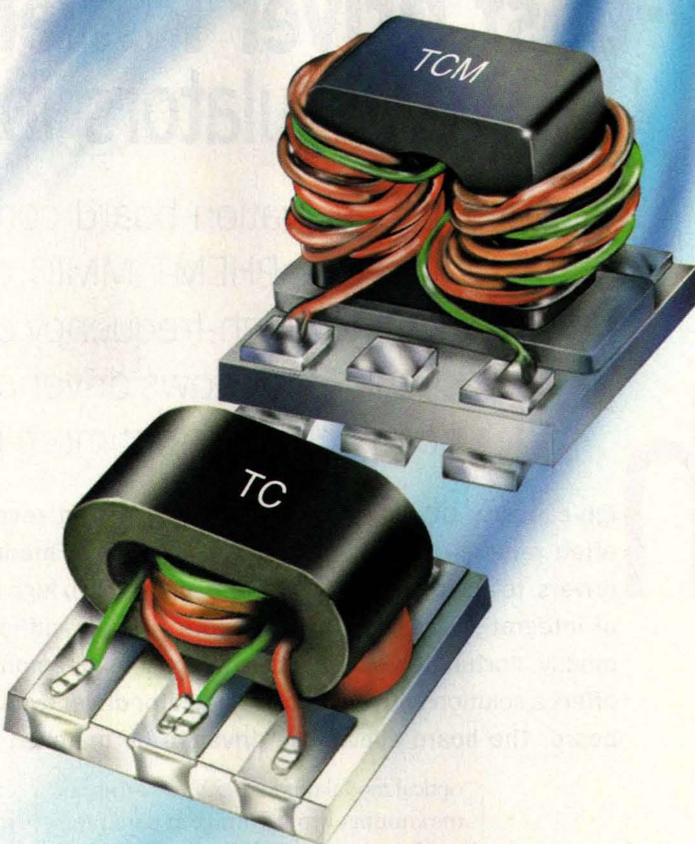
8. This representation captures the Momentum-Virtuoso mesh-refinement process.

dielectric loss, and skin-effect loss. **Figure 7** shows a comparison chart of parameters that are calculated by Momentum's microwave and RF/MW modes, as compared with SPICE.

Both modes generate a mesh before simulating the circuit. The resulting rectangular and triangular cells in the mesh are used to compute a set of S-parameters for a circuit. Calculating currents in each cell can require significant computer memory and computation time. However, Momentum uses a mesh-reduction technology to combine rectangular and triangular cells, producing a mesh of polygonal cells **(Fig. 8).** The reduction eliminates low-quality slivery cells and electromagnetically redundant interactions. The resulting mesh contains far fewer cells, which requires much less computer memory and computation time for a highly accurate set of S-parameters at RF frequencies.

The RF Design Environment provides the time- and frequency-domain tools needed by RF/analog/mixed-signal IC single-chip transceiver designers from within the familiar Cadence design environment. Version 2003C of the RF Design Environment extends these frequency domain simulation technologies to incorporate wireless test benches, and accurate EM-based layout modeling. **Agilent Technologies, 30699 Russell Ranch Rd., Suite 170, Westlake Village, CA 91362; (818) 879-6200, FAX: (818) 879-6346, e-mail: eesof@agilent.com, Internet: www.agilent.com/find/eesof.**

RF TRANSFORMERS



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TC1.5-1	1.5D	.5-2200	2-1100	1.59
TC2-1T	2A	3-300	3-300	1.29
TC3-1T	3A	5-300	5-300	1.29
TC4-1T	4A	.5-300	1.5-100	1.19
TC4-1W	4A	3-800	10-100	1.19
TC4-14	4A	200-1400	800-1100	1.29
TC8-1	8A	2-500	10-100	1.19
TC9-1	9A	2-200	5-40	1.29
TC16-1T	16A	20-300	50-150	1.59
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TCML1-19	1G	800-1900	900-1400	1.09
TCM2-1T	2A	3-300	3-300	1.09
TCM3-1T	3A	2-500	5-300	1.09
TTCM4-4	4B	0.5-400	5-100	1.29
TCM4-1W	4A	3-800	10-100	.99
TCM4-6T	4A	1.5-600	3-350	1.19
TCM4-14	4A	200-1400	800-1000	1.09
TCM4-19	4H	10-1900	30-700	1.09
TCM4-25	4H	500-2500	750-1200	1.09
TCM8-1	8A	2-500	10-100	.99
TCM9-1	9A	2-280	5-100	1.19

Dimensions (LxW): TC .15" x .15" TCM .15" x .16" ❖Referenced to midband loss.

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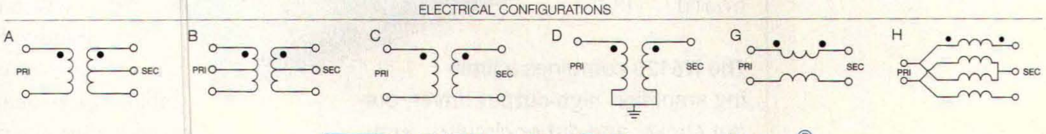

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Low-Cost Driver Powers OC-192 Modulators To 12.5 Gb/s

This evaluation board combines a limiting amplifier, PHEMT MMIC driver, RF power detector, high-frequency choke, and dither circuit, and allows driver and modulator to be matched for optimum performance.

ANDREA BETTI-BERUTTO
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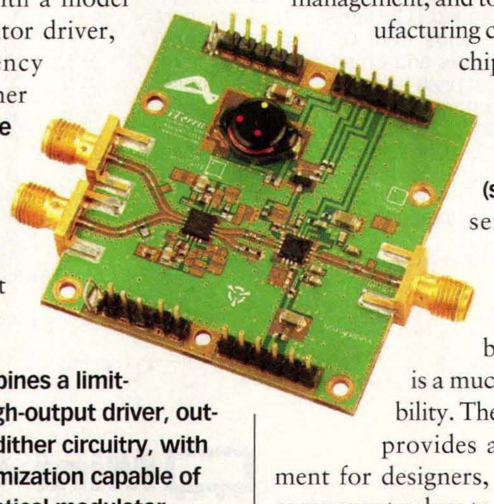
iTerra Communications, 1585 Reliance Way, Fremont, CA 94539; (510) 657-1751, FAX: (510) 657-1313, e-mail: andrea_berutto@iterrac.com, Internet: www.iterrac.com.

High-capacity OC-192 optical transmitters and receivers often require optimized components, such as modulator drivers, to achieve the best performance. Due to high levels of integration, such components are typically difficult to modify. Fortunately, iTerra Communications (Fremont, CA) offers a solution with its iT6120 modulator driver evaluation board. The board allows the driver to be matched to an optical modulator for 6.5 V peak-to-peak maximum output voltage at data rates to 12.5 Gb/s. The iT6120 modulator driver board provides on-board RF power detection, dither input, and a high-frequency output choke.

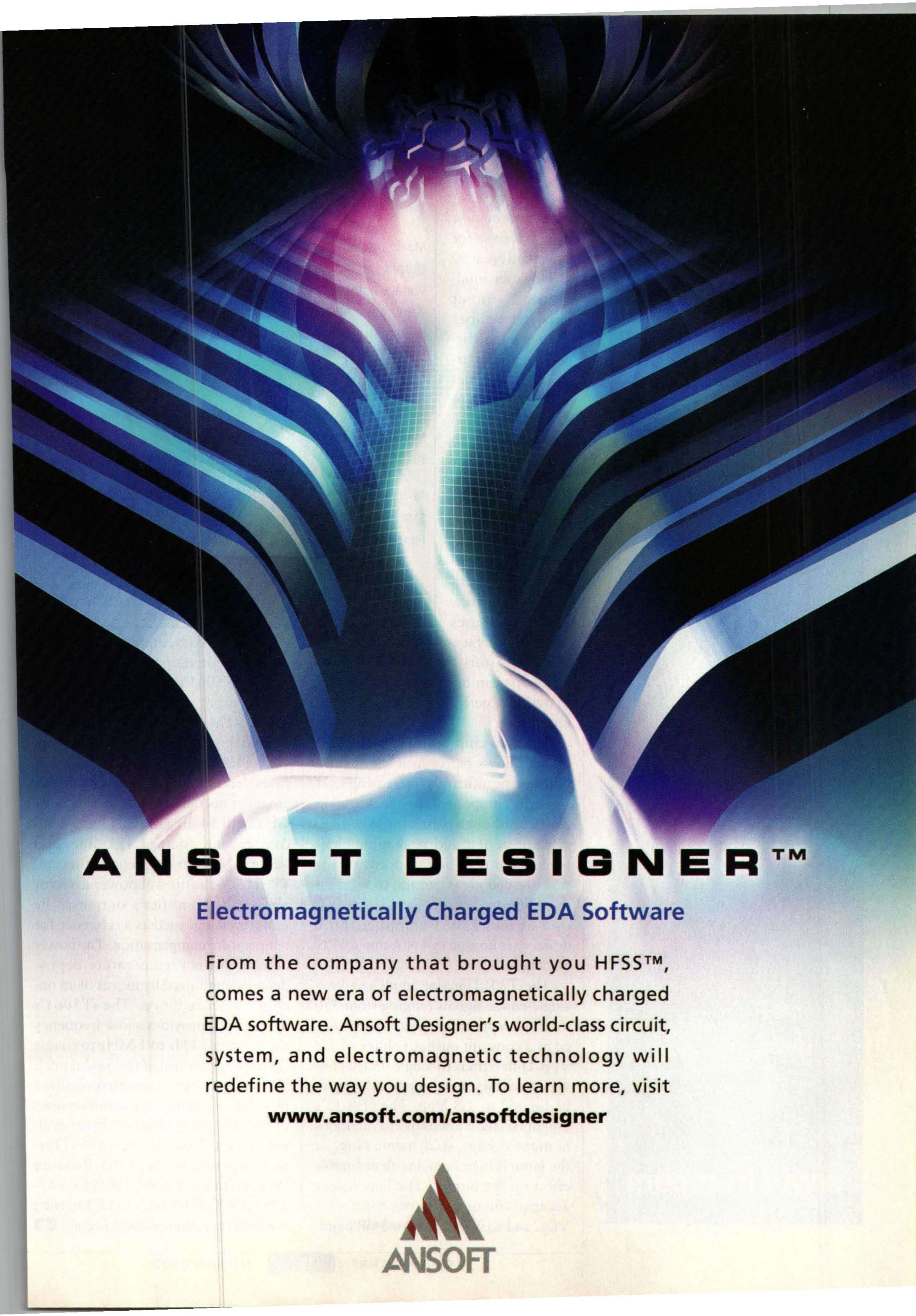
The iT6120 is designed to drive electro-absorptive, Mach-Zehnder, and $LiNbO_3$ modulators. It consists of a model iT3012 limiting amplifier cascaded with a model iT5061 modulator driver, a high-frequency choke, and dither input circuitry **(see figure)**. Components are mounted on a two-layer printed-circuit board (PCB) measuring 1.9 × 2.0 in. (4.8 × 5.08 cm). The top layer of the board is a polytetrafluoroethylene (PTFE) laminate capable of supporting microwave data rates while the FR4 bottom layer is suitable for distributing DC.



The iT6120 combines a limiting amplifier, high-output driver, output choke, and dither circuitry, with impedance optimization capable of matching any optical modulator.

Among the company's goals in creating the iT6120 were to extend its maximum data rate to 12.5 Gb/s for forward-error-correction (FEC), to allow impedance matching adjustments to be made, to employ a two-chip rather than single-chip solution for better thermal management, and to achieve low manufacturing cost by housing the chips in plastic rather than ceramic packages.

The iT6120 **(see table)** was chosen to satisfy the needs of long-haul applications, in which the greater bandwidth for FEC is a much-requested capability. The evaluation board provides an open environment for designers, who can modify component values to provide optimum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Electronic engineers typically create designs that require hundreds and, sometimes, thousands of different components from a wide range of suppliers. Finding the optimum components for a design from a reliable vendor can be an exercise in futility without the proper research tools. And one of the most important reference sources is the online version of the Microwaves & RF Product Data Directory, at www.m-rf.com.

This powerful website and search engine offers thousands of high-frequency manufacturers, searchable by means of more than 500 different product categories, from amplifiers to wire. The site provides access to names, addresses, telephone numbers, FAX numbers, e-mail addresses, and even provides active links to key suppliers.

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performance with specific modulators. For example, the output impedance of most drivers is fixed for a standard eye at 50 Ω. However, modulator input impedance varies from manufacturer to manufacturer and sometimes even from part to part. If there is no convenient way to raise or lower impedance to match the impedance of the modulator, it is difficult or impossible to achieve optimum performance. The iT6120 uses low-cost surface-mount-technology (SMT) resistors for drain-load resistance that can be changed by the user to optimize performance for a specific modulator.

iT6120 specifications at a glance

BIT RATE	9.95 TO 12.5 Gb/s
Input voltages Single-ended Differential	 300 to 900 mVpp +/-250 to +/-900 mVpp
Maximum output voltage	6.5 Vpp
Output voltage stability	+/-4 percent
Voltage control range	3.5 to 6.5 Vpp
Gain ripple (30 kHz to 8 GHz)	+/-0.75 percent
Maximum additive power dissipation	1.6 W
Eye crossing control	30 to 70 percent
3-dB low-frequency cutoff	30 kHz
3-dB high-frequency cutoff	8 GHz, 10.5 GHz saturated
Maximum RMS jitter	1.1 ps
Bias supply	-5.2 and +5 VDC, MSA compatible
RF input ports	AC or DC coupled, SCFL
Size	1.9 × 2.0 in.
Features	Power detector with reference diode, integrated choke for output stage bias, AM low-frequency modulation (dither) input, adjustable output impedance

The two-chip approach taken by iTerra allows better heat dissipation without significantly increasing cost since the components are packaged in plastic. Although plastic presented significant design and packaging challenges, the resulting cost advantage was deemed great enough to warrant the additional effort, such as passivation of the iT5061 amplifier. Both devices are housed in 4 × 4-mm QFPN packages.

The iT3012 limiting amplifier allows single-ended signals ranging from 350 to 800 mVpp at the input to be limited at a constant output voltage of 1.8 Vpp. Differential-to-single-ended conversion allows signals up to 1.6 Vpp to be limited to 1.8 Vpp. The iT3012's output voltage is insensitive to variations in input voltage, so dynamic range at the input is maintained with negligible effect on the output. The bias supply accepts voltages ranging from –5.2 VDC and +5 VDC. It has a 3-dB bandwidth of 11 GHz, and provides external offset correction.

The iT5061 modulator driver acts as the output stage for the evaluation board. The traveling-wave MMIC amplifier is fabricated with a 0.15-μm GaAs PHEMT process that supports bit rates from 9.95 to 12.5 Gb/s. The amplifier operates from DC through 11 GHz with 14 dB gain, and has a 1-dB compression point of +21 dBm, and +23 dBm output power at saturation. The iT5061's integral power detector allows the amplifier's output to be monitored and used as a reference for temperature compensation. The power detector's own temperature dependence is minimized by means of an on-chip reference diode. The iT5061's dither input provides a low-frequency signal from 1 kHz to 1 MHz to enable closed-loop control of the modulator's DC biasing. For those with specialized physical requirements, custom versions of the iT6120 modulator driver evaluation board are also available. **iTerra Communications, 1585 Reliance Way, Fremont, CA 94539, (510) 657-1751, FAX: (510) 657-1313, Internet: www.iterracommunications.com.** MRF

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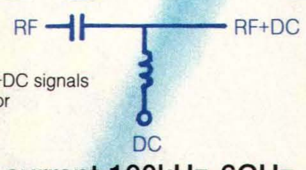

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▲ZFBT-4R2G	10-4200	0.15	0.6	0.6	32	40	50	1.13:1	59.95
▲ZFBT-6G	10-6000	0.15	0.6	1.0	32	40	30	1.13:1	79.95
▲ZFBT-4R2GW	0.1-4200	0.15	0.6	0.6	25	40	50	1.13:1	79.95
▲ZFBT-6GW	0.1-6000	0.15	0.6	1.0	25	40	30	1.13:1	89.95
▲ZFBT-4R2G-FT	10-4200	0.15	0.6	0.6	N/A	N/A	N/A	1.13:1	59.95
▲ZFBT-6G-FT	10-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.13:1	79.95
▲ZFBT-4R2GW-FT	0.1-4200	0.15	0.6	0.6	N/A	N/A	N/A	1.13:1	79.95
▲ZFBT-6GW-FT	0.1-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.13:1	89.95
★ZNBT-60-1W	2.5-6000	0.2	0.6	1.6	75	45	35	1.35:1	82.95
■PBTC-1G	10-1000	0.15	0.3	0.3	27	33	30	1.10:1	25.95
■PBTC-3G	10-3000	0.15	0.3	1.0	27	30	35	1.60:1	35.95
■PBTC-1GW	0.1-1000	0.15	0.3	0.3	25	33	30	1.10:1	35.95
■PBTC-3GW	0.1-3000	0.15	0.3	1.0	25	30	35	1.60:1	46.95
•JEBT-4R2G	10-4200	0.15	0.6	0.6	32	40	40	-	39.95
•JEBT-6G	10-6000	0.15	0.7	1.3	32	40	40	-	59.95
•JEBT-4R2GW	0.1-4200	0.15	0.6	0.6	25	40	40	-	59.95
•JEBT-6GW	0.1-6000	0.15	0.7	1.3	25	40	30	-	69.95

L = Low Range M = Mid Range U = Upper Range

NOTE: Isolation dB applies to DC to (RF) and DC to (RF+DC) ports.

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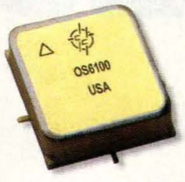
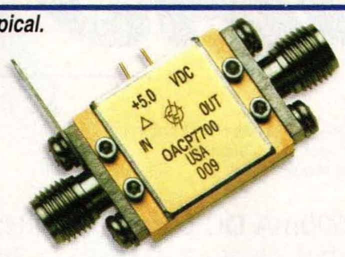
Oscillator with internal MMIC amplifier available in SMTO-8 or CougarPak™.								
OAS5100	4300-5100	0-15	13.0/2.0	-84/-108	50-85	-22	5.0	94
OAS6100	4700-6100	0-15	10.0/2.0	-80/-102	70-150	-25	5.0	95
OAS6500	5000-6500	0-15	13.0/2.0	-80/-102	80-160	-25	5.0	94
OAS6700	5300-6700	0-15	10.0/2.0	-75/-100	80-180	-30	5.0	95
OAS7700	5700-7700	0-15	10.0/2.0	-75/-100	70-250	-30	5.0	95
OAS8600	6500-8600	0-15	10.0/2.0	-70/-95	90-250	-30	5.0	95
OAS8900	6900-8900	0-15	10.0/2.0	-70/-95	100-270	-30	5.0	95
Oscillator only available in SMTO-8 or CougarPak™.								
OS5100	4300-5100	0-15	0/1.5	-85/-108	50-85	-12	5.0	25
OS6100	4700-6100	0-15	0/2.0	-80/-102	70-150	-12	5.0	26
OS6500	5000-6500	0-15	1.0/2.0	-80/-102	80-160	-17	5.0	26
OS6700	5400-6700	0-15	0/2.0	-75/-100	80-180	-17	5.0	25
OS7700	5700-7700	0-15	2.0/2.0	-75/-100	70-250	-17	5.0	25
OS8600	6500-8600	0-15	1.0/2.0	-70/-95	90-250	-20	5.0	25
OS8900	6900-8900	0-15	1.0/2.0	-70/-95	100-270	-25	5.0	24

Specifications are typical.





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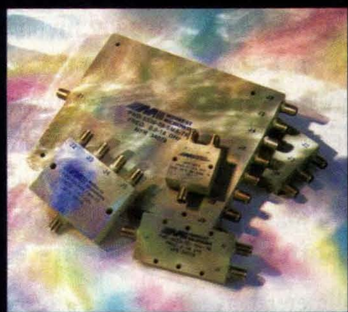

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Novel Materials Form Tunable Components

Tiny voltage-tuned phase shifters are among the first components offered by a company with unique thin-film ferroelectric technology.

JACK BROWNE
Publisher/Editor

Tuning a high-frequency circuit usually involves trimming a variable capacitor or turning a mechanical tuner. By using innovative circuit materials formed of barium-strontium-titanate (BST) dielectric, however, Agile Materials & Technologies (Goleta, CA) offers components that can be tuned with an applied voltage. The company's thin-film ferroelectric technology offers tuning benefits at RF through millimeter-wave frequencies for commercial and military applications, including for antennas, filters, phase shifters, and linearization circuitry.

Since the dielectric constant of BST-based substrate materials changes with applied DC voltage, circuits can be readily fabricated with voltage-tunable capacitances. As with trimmer capacitors, as the capacitance is varied, the impedance and phase responses of an active or passive circuit are adjusted in a predictable way. In the case of Agile's components, however, the circuit board is the trimmer capacitor. For a variable capacitor formed on BST substrate with zero-voltage value of 32 pF, the capacitance drops to half 16 pF with an applied voltage of ±4 VDC. Once the tuning voltage has been applied to affect the capacitance shift, additional voltage need not be applied to maintain the change in capacitance and only a small leakage current is consumed.

At the recent IEEE MTT-S exhibition in Philadelphia, PA, the company demonstrated several BST components, including tunable phase shifters. The phase shifters operate with a single analog tuning voltage, requiring a maximum control voltage of 20 V. Since only passive components are used in the phase shifters (compared to diodes in conventional phase shifters), and the control voltage draws zero amperes of nominal current, the power consumption for this design is negligible. The phase shifters, which are available at frequencies from below 1 GHz to beyond 40 GHz (L-band through Ka-band), achieve better than 360-deg. Phase-shift rage with 6 to 7 dB or less typical insertion loss at 0-deg. phase shift, improving to 4 to 5 dB or less of insertion loss with increased phase shift. The phase shifters feature a distributed design with uniform group delay, and can handle more than +20 dBm (100 mW) input power over wide instantaneous bandwidths. They take up only 3 to 6 mm^2 circuit-board area, depending upon frequency, allowing designers to shave the size of circuit layouts. **Agile Materials & Technologies, Inc., 93 Castilian Dr., Goleta, CA 93117; (805) 968-5159, FAX: (805) 968-3279, Internet: www.agilematerials.com.**

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▪ *M3SWA-2-50DR*	*DC-4.5*	*65*	*0.7*	*25*	*4.95 **
					(Qty. 1-9)
• ZASW-2-50DR	DC-5	90	1.7	20	89.95
▪ *ZASWA-2-50DR*	*DC-5*	*90*	*1.7*	*20*	*89.95*

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CD-ROM Course Teaches Filter Design

This "RF classroom-on-a-CD" provides instructional lessons, design examples, helpful follow-up questions, and a variety of reference and supplemental information.

JACK BROWNE
Publisher/Editor

Engineers faced with pressing deadlines and excessive demands for their time may lack the opportunity to participate in continuing education courses at an accredited institution. But most engineers should be able to find the time to investigate a concise course on filter design from Noble Publishing. Entitled "Filter Design By Transmission Zeros," this short course is supplied on a single CD-ROM that will turn just about any personal computer (PC) into a personal RF classroom.

The CD-ROM is divided into 48 course segments. For a computer to properly run the course software, it should be equipped with Version 4 of QuickTime for Windows as well as Adobe Acrobat Reader, although installers for both tools are also included on the CD-ROM. Once loaded, the course can run continuously from segment to segment (and section to section), or a student can use the "Course Outline" section to quickly jump to different segments of the course.

The course's five sessions are Classic Filter Design Review, Transmission Zero Introduction, The Extraction Process, Network Transforms, and Practical Issues. Course narration is clear and well paced, provided by Eagleware (Norcross, GA) founder Randy Rhea, well known for his technical workshops on filter and oscillator design.

The first session includes a brief history of filters; how prototype lowpass-filter designs can be scaled to create other types of filters at higher frequencies, such as bandpass filters; and some of the limitations of designing filters by transforming prototypes. The second session, in contrast, explains how direct synthesis of filter designs supports a variety of topologies and allows the designer to place transmission zeros at precise frequen

The third session details the extraction process for creating a new filter design, showing a conventional extraction sequence along with some general extraction sequences. It then explains how to choose an extraction sequence.

The fourth session highlights network transforms, including how to apply a Norton series transform to the creation of a 70-MHz intermediate-frequency (IF) bandpass filter. The final session provides a detailed example of a lowpass-filter design based on a requirement for a passband of DC to 850 MHz with less than 1-dB passband insertion loss and 12-dB passband return loss. The CD-ROM requires a PC with Windows 95, 98, 2000, or NT, and a Pentium II processor at 333 MHz or faster. **Noble Publishing Co., 630 Pinnacle Ct., Norcross, GA 30071; (770) 449-6774, FAX: (770) 448-2839, Internet: www.noblepub.com.**

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S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
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S10W2	S10W5	N10W5	10	±0.60
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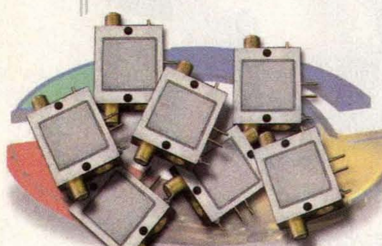

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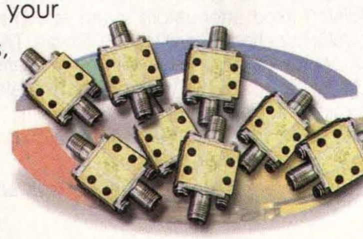

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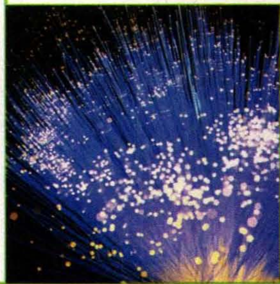

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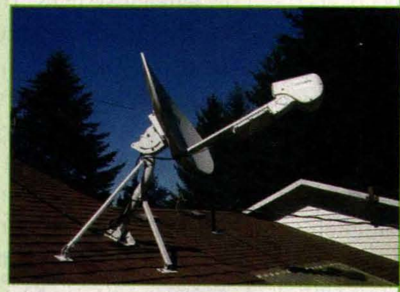

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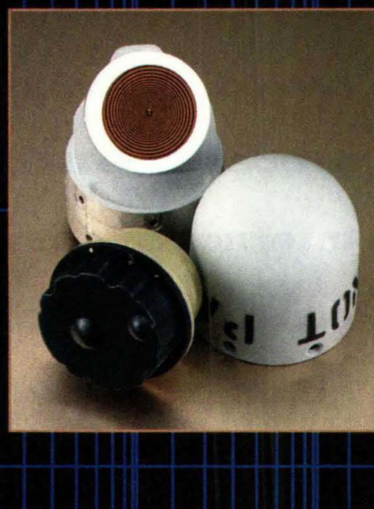

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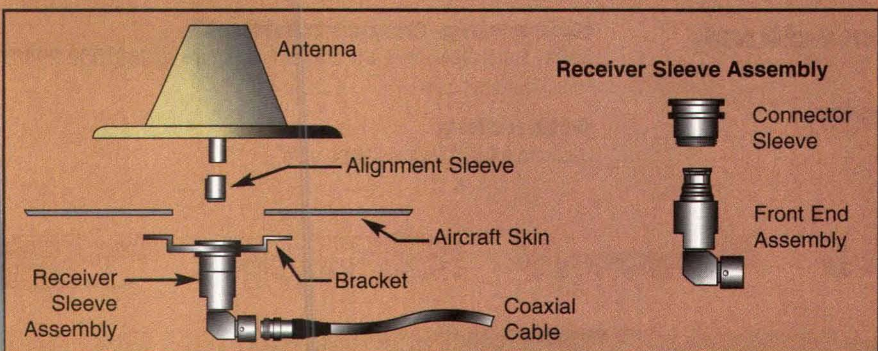

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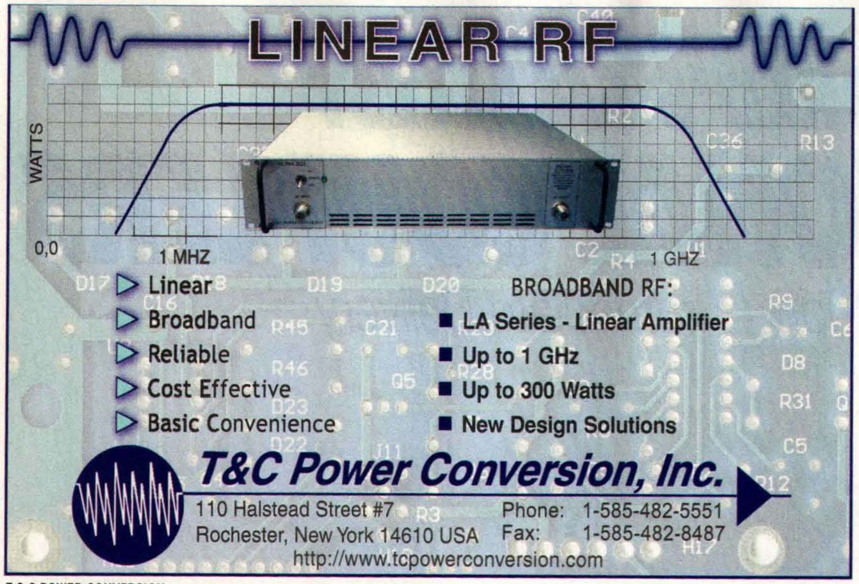

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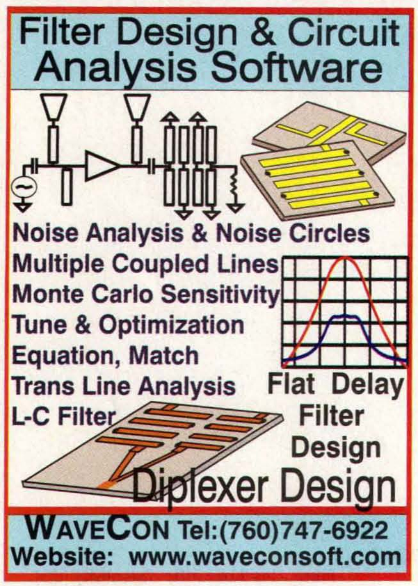

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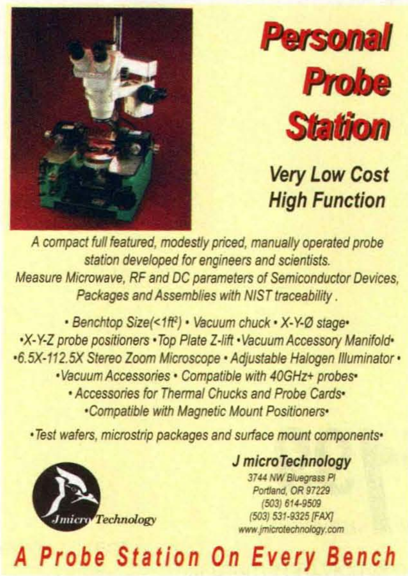

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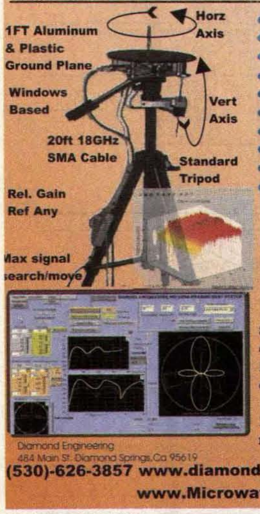

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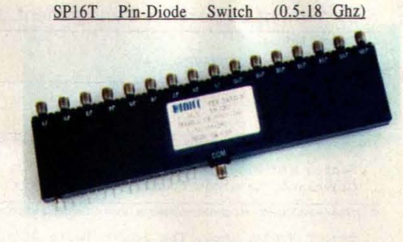

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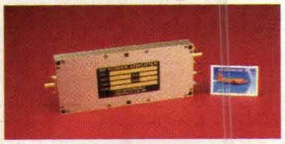

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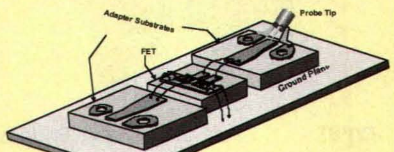

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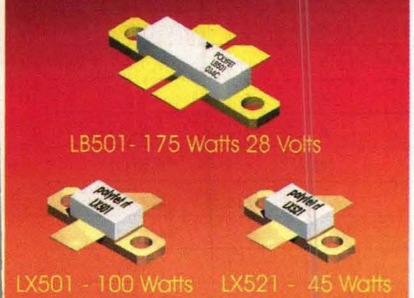

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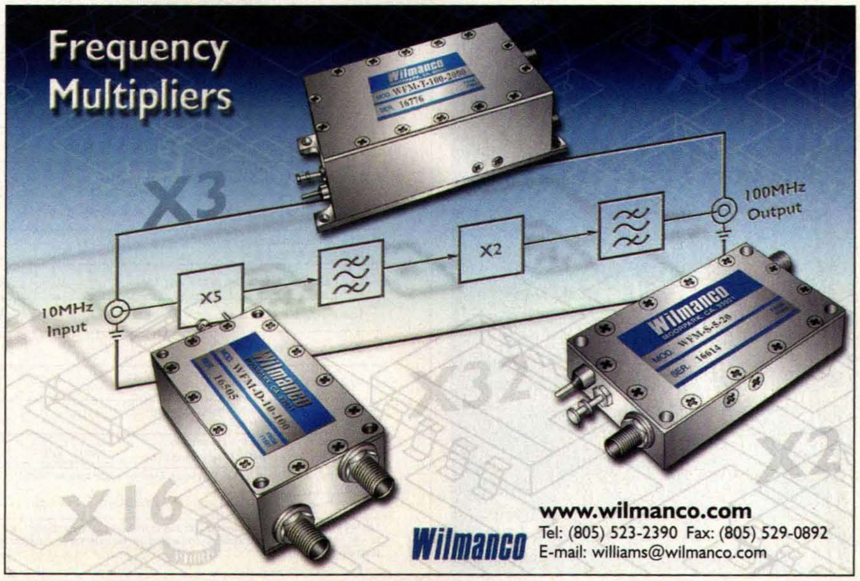

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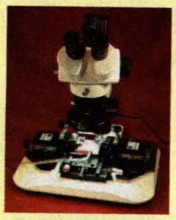

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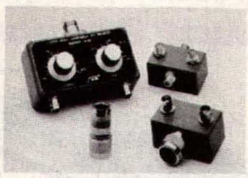

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looking back

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Se Puan Yu were part of a team at General Electric
NY) to develop a 1-μm silicon-on-sapphire MESFET
capable of 0.6 W output power and 6-dB gain at 3 GH

next month

Microwaves & RF December Editorial Preview

Issue Theme: Amplifiers & Oscillators

News

December begins a trilogy of three exclusive reports in three months previewing the first year of the Wireless Systems Design Conference & Exhibition in San Diego, CA. This first preview will explore the conference's diversification into application areas other than cellular, including technical presentations on network security, uses for radio-frequency identification (RFID) chips, and advanced implementation of digital-signal-processing (DSP) technology.

Design Features

In December, the Design Features section supports the issue's communications theme with a review of recent advances in ultra-narrowband modulation methods for high-date-rate communications. Additional articles detail the design of short, high-Q resonators using commercial computer-aided-engineering (CAE) software, how to characterize reed relays for applications through 10 GHz, and the design of direct-modulated 2.4-GHz radio transmitters for short-range communications.

Product Technology

The December Product Technology section will celebrate that annual editorial event known as the Top Products of the Year, in which a dozen or so outstanding product introductions are celebrated in a Special Report. Additional product features will examine a family of miniature highpass filters with cutoff frequencies from 600 to 3000 MHz fabricated on low-temperature-cofired-ceramic (LTCC) substrate materials as well as two lines of low-phase-noise, fast-switching frequency synthesizers from two different suppliers in New Jersey. In addition, December will offer a first look at a highly practical, battery-powered RF field monitor that can check signals from co-located wireless transmitters for FCC compliance, as well as a review of an upgraded line of spectrum analyzers for measurements to 325 GHz.

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3.95- 5.85	750	187-925	2000	187-920
4.90- 7.05	625	159-925	1500	159-920
5.85- 8.20	500	137-925	1000	137-920
7.05-10.0	425	112-925	600	112-920
7.00-11.0	325	102-925	500	102-920
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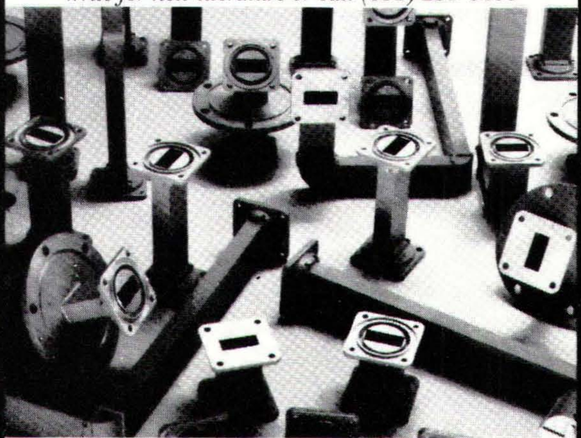

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